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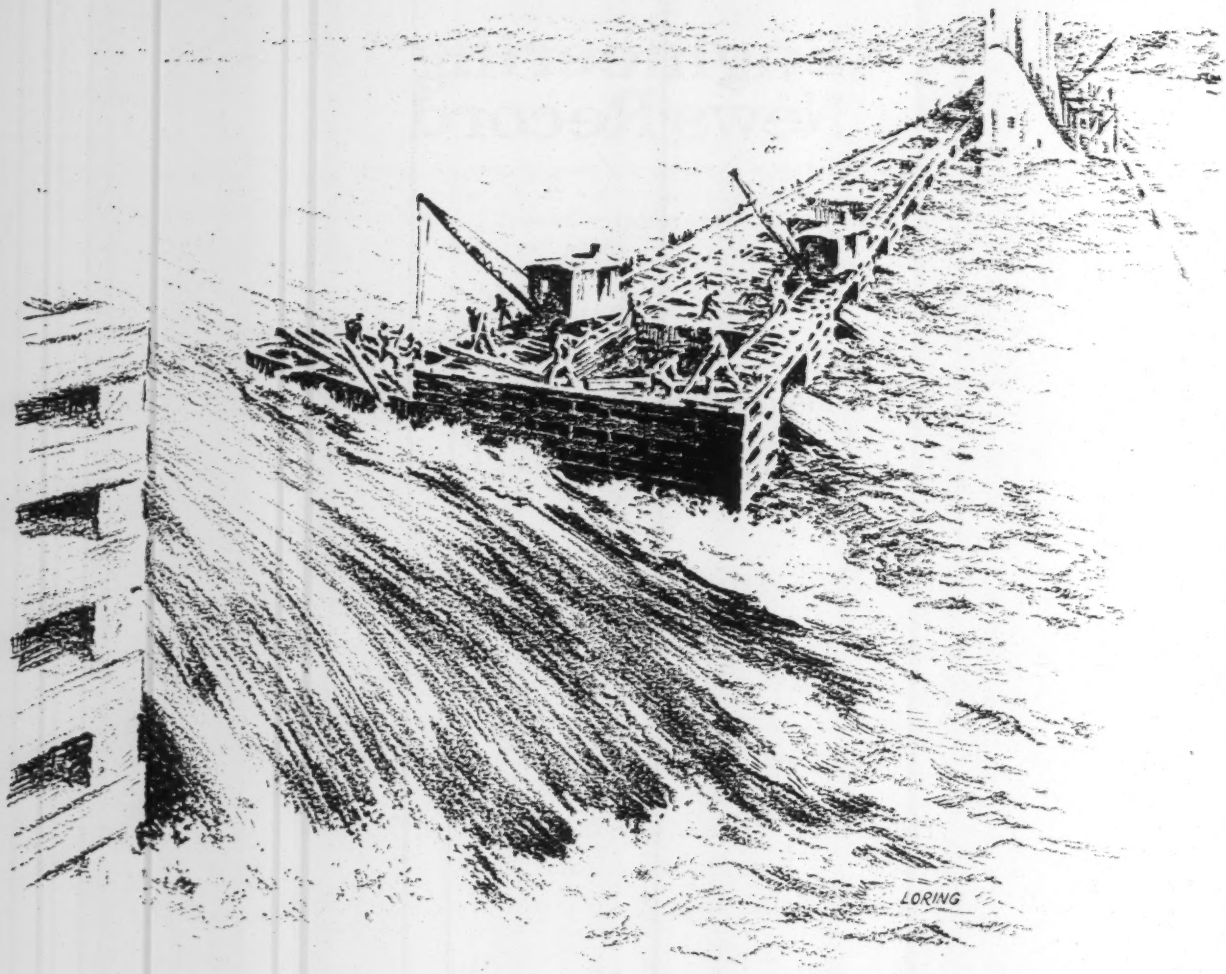

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Engineering News-Record

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Ten Articles on Hoover Dam Planning and Construction

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From Colorado River Compact to the Closure of Black Canyon

Tracing the major factors in carrying forward a gigantic engineering enterprise from the ten-year struggle of the seven basin states to the successful diversion of the river

EXACTLY a decade has elapsed between the signing of the Colorado River Compact in November, 1922, and the diverting of the river at the Hoover Dam site in Black Canyon in November, 1932. These two dates are the significant mileposts in the progress of curbing and utilizing the destructive forces of the great river system. During this ten-year period a complete program was developed for controlling the river, which would eliminate the serious flood menace that has threatened the rich Yuma and Imperial districts and other parts of the lower valley, equalize and conserve the flow of the river, build the All-American Canal with its many important advantages to the Southwest, and provide Southern

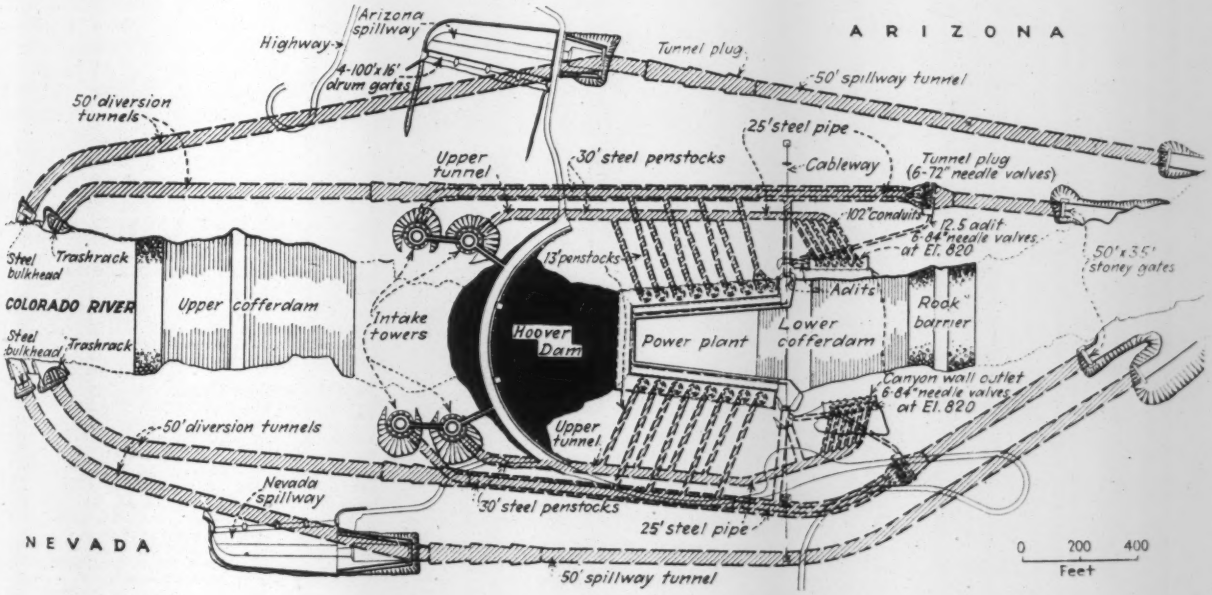

Fig. 1—Plan of the Hoover Dam project, showing all appurtenant works.

California with a water supply vital to ultimate growth of its metropolitan area.

Evolution and finally execution of this program moved forward with slowly gathering speed, marked by brisk acceleration in 1930, when the project became a prominent part of the national public-works building program. This review is intended to outline in brief form the events and important steps taken in the progress leading up to the construction program that is now well advanced on the Colorado River.

Ultimate control and full utilization of the Colorado has long been a major ambition of the Southwest. Lacking flood control and storage facilities, irrigation from the river has ever been precarious. Again and again extensive crop failures have followed periods of extreme low flow, while in high-water seasons floods have swept over irrigated lands, leaving destruction in their wake. Equalization of river flow is of utmost importance to the lower basin.

For years the present system of bringing waters from the Colorado River into the Imperial Valley through Mexican territory has been the subject of dissension because of the original contract of the Imperial Irrigation District with Mexico to give the latter one-half

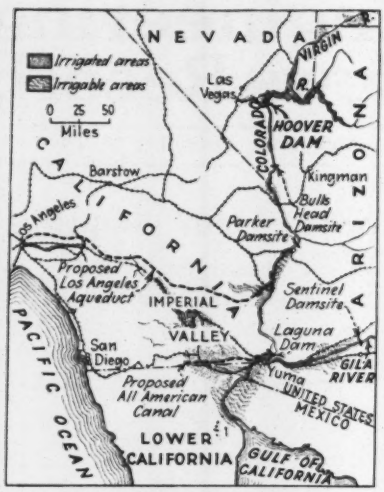

Fig. 3—Map of the territory affected by the Hoover Dam project.

of the flow in the main canal if demanded. The All-American Canal has long been advocated to ease this situation. The cost of the canal always seemed prohibitive, however, especially as the shortage of water in dry seasons still remained. It was not until the canal project could be tied in with a storage plan into a single great undertaking for controlling the river that its construction was made possible.

Many plans for the development of the river have been presented in years past, mainly based on power exploitation. The upper basin states were always disturbed over the possibility that such plans might establish water rights to the permanent disadvantage of their interests. At the same time the lower basin was worried over actual and threatened diversion of water in the upper reaches of the river.

The Colorado River Compact

With this background, the common interest of the states forming the drainage basin of the Colorado River and the importance of the stream in the economic future of the Southwest prompted the passage late in 1922 of a Congressional act permitting a historic meeting of all the states interested. The meeting was held at Santa Fe. It was attended by representatives of the seven states of the river basin and was presided over by Herbert Hoover, then Secretary of Commerce, as a representative of the government. The result of this meeting was an agreement which allocated 7,500,000 acre-ft. of flow (averaged for ten years) to the upper basin states (Utah, Colorado, Wyoming and New Mexico) and 7,500,000 acre-ft. to the lower basin states (Nevada, Arizona and California). This agreement, ratified within six months by all the states with the exception of Arizona, formed the basis for immediate activity in Congress by representatives of California, the state most vitally interested.

It is significant that during the intervening years there has been no further tangible progress toward settling the question of water allocation between the states, even though the program for actual development is now well under way. During this period there have been repeated conferences between governors and special representatives of the seven states as a group and in the two divisions of the group; but the many involved questions as to division of the water and power still remain unsolved. The various suggestions proposed at these meetings and the divergence of the points of view are not part of the present review, particularly since the results have been negligible. An extentive study is now being made by the Bureau of Reclamation of the entire river and its development possibilities.

Fig. 2—The blast that marked the end of eighteen months' preliminary work by diverting the river into the two Arizona tunnels. Downstream portals of the two inner tunnels can be seen on either side of river. Barrier part way across stream is start of lower cofferdam.

MAJOR ARTICLES ON THE HOOVER DAM PROJECT PUBLISHED IN PREVIOUS ISSUES OF ENGINEERING NEWS-RECORD

Economic Development..Feb. 6, 1930, p. 240
Engineering Plans.....Feb. 6, 1930, p. 247
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Preliminary Activities..May 28, 1931, p. 895
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Building Boulder City....Nov. 26, 1931, 846
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Aggregate Plant .....June 2, 1932, p. 783
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Design of 150-Ton Cableway, Oct. 6, 1932, p. 408
Cement Specifications..Nov. 10, 1932, p. 558
Preparing for River Diversion, Nov. 24, 1932, p. 622

SOME IMPORTANT DATES IN THE COLORADO DEVELOPMENT PROGRAM

Nov. 24, 1922
Signing of Colorado River Compact at Santa Fe.
April 2, 1923
Ratified by sixth state—Utah.
January, 1924
Swing-Johnson Bill first introduced.
July, 1928
Colorado River Commission appointed.
Nov. 24, 1928
Colorado River Commission reported.
Dec. 24, 1928
Boulder Dam Act signed by President Coolidge.
June 21, 1929
Act becomes effective, 6 months, 6 states agreeing.
Oct. 21, 1929
Allocation of power announced.
April 26, 1930
Power contracts signed.
July 7, 1930
Field work started by Bureau of Reclamation.
Sept. 17, 1930
Official starting ceremony—named Hoover Dam.
Dec. 17, 1930
Specifications approved and bids asked.
March 4, 1931
Bid opened; Six Co. Inc. low at $48,890,995.
April 20, 1931
Contract signed by Secretary Wilbur.
May 18, 1931
Supreme Court declares act valid.
June 13, 1931
Power line completed for delivery at site.
Sept. 1, 1931
Desilted water first pumped to Boulder City.
Jan. 9, 1932
Initial operation of 500-ton gravel-screening plant.
March 8, 1932
First "pay concrete" placed at No. 2 tunnel portal.
Nov. 13, 1932
River diverted into tunnels.

in accordance with the provisions of the Boulder Dam Act, and the results may form the basis for more future agreements. The protection of future development rights by individual states is a point of major disagreement, and the entire problem is complicated by international water claims.

Purpose—The purpose of the development program, as outlined in the act itself, is: (1) to control floods, (2) improve navigation, (3) regulate flow, (4) provide for irrigation development, (5) provide domestic water supply and (6) generate power.

Most important of the flood-control problems is the protection of the Imperial Valley, lying on the California side of the river just north of the international line. Here the river flows in a channel on top of a broad, flat inland delta, whose surface is about 200 ft. above the floor of the valley. With extensive agricultural development and municipal improvements in the valley, the hazard of a break-out, repeating the events of 1903-05, is large and serious. At present a levee system protects the valley and the vicinity of Yuma on the Arizona side, but only the lower flood peaks of recent years have prevented disaster. The river's annual silt burden of 100,000 acre-ft. aggravates the situation, as it fills the channels, builds up the delta, causes the river to shift, and forms great deposits in the irrigation canals.

ORGANIZATION OF THE U. S. BUREAU OF RECLAMATION IN CHARGE OF HOOVER DAM CONSTRUCTION

Elwood Mead, commissioner, administrative head, Washington, D. C.
Executive Office, Denver
R. F. Walter, chief engineer
S. O. Harper, assistant chief engineer
J. L. Savage, chief designing, engineer
W. H. Nalder, assistant chief designing engineer
L. N. McClellan, chief electrical engineer
E. W. Steele, designing engineer on dams
H. R. McBirney, designing engineer on canals
C. M. Day, mechanical engineer
E. B. Debler, hydraulic engineer
P. J. Preston, engineer in charge Colorado River investigations
Ivan E. Houk, engineer on technical studies
E. W. Lane, research engineer
Boulder City Field Office:
Walker R. Young, construction engineer
Ralph Lowry, field engineer
John C. Page, office engineer

Irrigable lands on the Colorado, below Hoover Dam site are divided about as follows: California, 1,200,000 acres; Arizona, 900,000 acres, Nevada 15,000 acres. The present 520,000 acres of irrigated area in the Imperial Valley could be more than doubled under service from the All-American Canal, and a branch could serve an area of 150,000 acres in the Coachella Valley to the north. Also 80,000 acres in the Palo Verde project near Blythe are irrigable. Arizona lands are mainly in the Parker-Gila Valley project (600,000 acres), a study of which development is authorized by the act. The major part of the remaining area is divided between the Parker project (115,000 acres) and the expansion of the present federal reclamation project at Yuma.

The feature of domestic water supply, although mentioned next to last, undoubtedly exerted the strongest urge for the project. Los Angeles and the surrounding area, as a result of phenomenal population growth, several years ago began to look toward the Colorado River as their ultimate source of supply. A million acre-feet per year (1,500 sec.-ft.) was set as the ultimate requirement for the metropolitan area. To obtain such a supply required large-size storage on the river by dams located in other states. The power produced at such dams was equally important for the pumping required on the aqueduct line.

Passing the Act—The combined urge of this requirement for a metropolitan supply and the menace of floods, both in Southern California, impelled and sustained the long fight for the enactment of the so-called Swing-Johnson Bill or Boulder Dam Act by Congressional members from that state. During the early consideration of this measure in Congress the controversy between basin states, which made impossible a united front on any development program, tended to defeat prompt action because Congress naturally looked for agreement on the part of a section of the country most interested in securing federal assistance for such a problem. The differences of opinion as to program, advisability, matters of power development and even the technical problems of constructing a dam of record-breaking size remained open questions. Western interest varied all the way from active, as in the case of California which was to secure the major immediate benefit, through passive agreement, neutrality and finally aggressive opposition, as in the case of Arizona, which contended and continues to contend that its rights have not been sufficiently considered.

In the spring of 1927 the question was quite active, and the Secretary of the Interior, in order to reach an opinion on the subject, appointed a non-technical advisory board to determine certain broad questions on the entire river-development program. Four out of five on the commission favored immediate development of the river, stressing the need for flood control.

Congress authorizes project

During the early months of 1928 a revised form of the Swing-Johnson Bill was again actively before congressional committees, and it was expected that the matter would be finally settled before adjournment. About this time the St. Francis Dam disaster occurred and, by placing emphasis on the uncertainties of foundation work and strength of dam structure, became one of several factors leading to deferring action and instrumental in providing for a joint resolution for appointment of a board of review to consider all engineering and economic features.

In accordance with this resolution the Secretary of the Interior selected a board of five engineers and geologists, approved by the President, to study the entire Colorado River program. The commission was composed of: W. L. Sibert, major-general, U. S. Army, retired; D. W. Mead, professor of hydraulic engineering of the University of Wisconsin; Robert Ridgway, chief engineer of the Board of Transportation of New York; Charles P. Berkey, professor of geology at Columbia University; and W. J. Mead, geologist at the University of Wisconsin. Under the congressional resolution the commission was authorized to report on "matters affecting safety, the economic and engineering feasibility and the adequacy of the proposed structure and incidental work." On Nov. 24, 1928, it reported (*ENR*, Dec. 13, 1928, p. 887) that (1) the Black Canyon site is best, is feasible and safe; (2) the design should be conservative and should include larger flood provisions than contemplated in the designs so far made; (3) the All-American Canal is feasible; (4) Southern California is able to absorb the power developed at the site; and (5) the estimated cost of the entire project will be $165,000,000 and the construction period seven years.

It is particularly significant that within two weeks after this technical commission had reported favorably on the project and concluded that its engi-

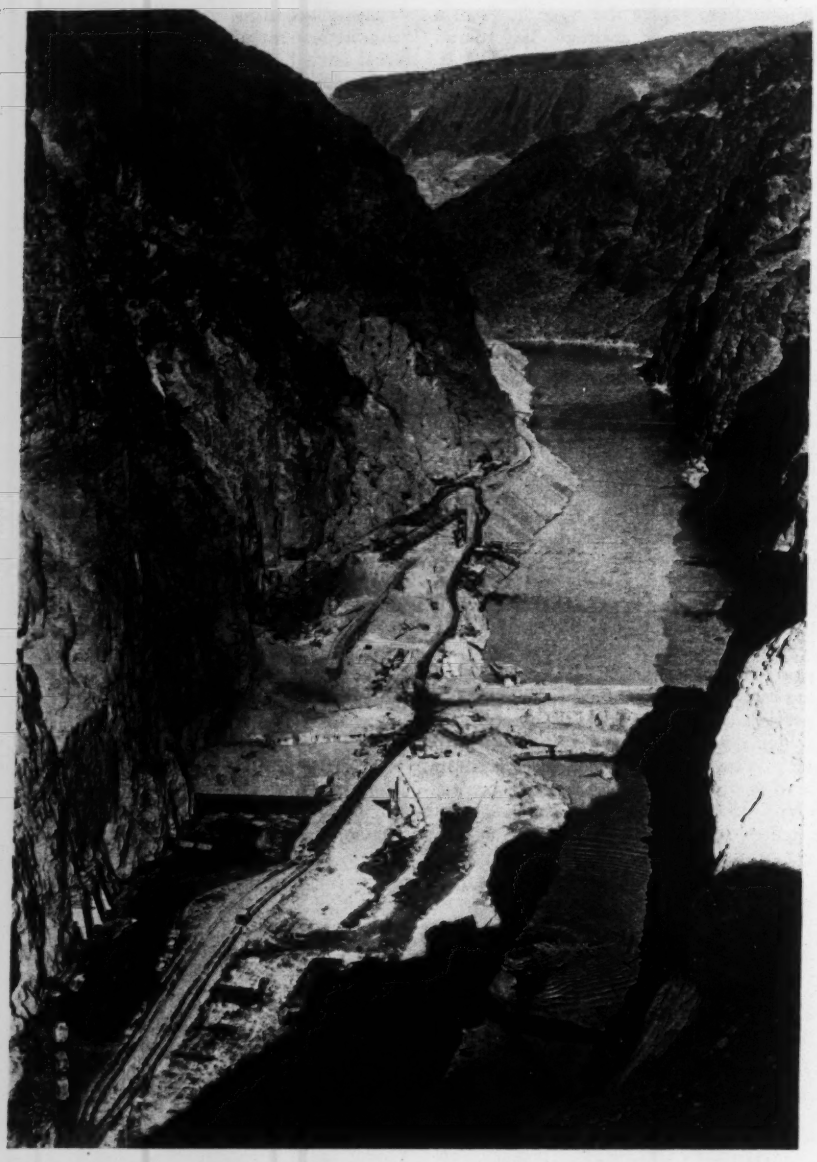


Fig. 4—Black Canyon as it is today. Looking upstream from point just above dam site. Work on upstream cofferdam is under way in foreground. River is blocked off by temporary barrier diverting water into two Arizona tunnels on right side. Terminus of gorge railroad can be seen in left center, where earth and gravel fill for cofferdam is being dumped. Bridge against canyon wall at left is to carry railroad line to dam site over upper portals of Nevada diversion tunnels.

neering and economic features were sound, Congress passed the Boulder Dam Act. It was signed by the President on Dec. 24, 1928. By the following March, six states had ratified the act, and on June 21, 1929, the act became effective, although Arizona had not ratified.

The next step was to secure power contracts by the Secretary of the Interior, sufficient in his opinion to repay the cost of the project at 4 per cent interest. Notices were sent to all prospective purchasers of power that applications stating the quantity of power, purpose and place of use should be filed before Oct. 1. The applications totaled more than double the available power and the allocation was announced by the Secretary Oct. 21 (*ENR*, Nov. 14, 1929, p. 772). Litigation threatened over the power allocation, and the final decision on allocation was reserved until another conference between Arizona and California should attempt to settle differences. Further differences arose over the allotment between the municipal interests of Southern California and the largest private interest, the Southern California Edison Co., as to questions of preference in the matter of agency for operating the power equipment. Differences were finally settled, and the power contracts were signed April 26, 1930.

Beginning of actual construction proceedings on the preliminary stages now awaited only the appropriation of funds.

In the meantime a raise of 25 ft. in the height of the dam had been suggested by the engineers of the Bureau of Reclamation and studied by the Board of Review, which reported favorably on the increase. The increase in height raised the reservoir capacity from 26 million to 30.5 million acre-feet and the continuous power output from 547,000 to 585,000 hp. (*ENR*, April 24, 1930, p. 701, and June 26, 1930, p. 1066).

Consulting Boards — As previously stated, prior to the passage of the Swing-Johnson Bill, which provided for the construction of the project, President Coolidge appointed the Colorado Board of Review composed of Gen. Wm. L. Sibert, Daniel W. Mead, William J. Mead, Charles P. Berkey and Robert Ridgway to pass upon the safety of the dam and the economic value of the undertaking. The Boulder Canyon Act called for its continuation and stipulated that no funds should be appropriated for the project until the plans were approved by this board.

Later another board was appointed by the Bureau of Reclamation for the purpose of consulting on concrete and cement problems. Members of this group were P. H. Bates, R. E. Davis, H. T. Gilkey, W. K. Hatt and F. R. McMillan. The bureau also selected another group for general consultation, consisting of A. J. Wiley, D. C. Henny and L. C. Hill. W. F. Durand was appointed to this board after the death of Mr. Wiley.

Getting started

Actual field work, to prepare for contract construction, was begun by the Bureau of Reclamation at the site on July 7, 1930, following approval of a $10,000,000 appropiation for preliminary work. Field work was concentrated on the railroad from the Union Pacific line near Las Vegas, to a new town that was to be built near the site, and on a water-supply system for the new town—Boulder City, Nev. Plans and specifications for the dam and major units were also being rushed in the Denver office. A contract for the 22-mile railroad spur was awarded in August. The official ceremony marking the beginning of work on the railroad, the first actual construction work on the project, was conducted by Secretary Wilbur on Sept. 17, at which time the name Hoover Dam was first applied to the structure.

Efforts of Arizona to delay the project continued, however. On Oct. 13 the Supreme Court of the United States allowed filing of a complaint by the state attacking the constitutionality of the act on numerous grounds, including: (1) discrimination between Arizona and California, (2) setting aside of state jurisdiction and control over its waters, (3) subjection to a compact without consent. The case was finally decided

seven months later, when on May 18, 1931, the act was declared constitutional and valid by the Supreme Court (*ENR*, May 21, 1931, p. 867).

Work on designs and specifications for the dam and river-control features was accelerated during the fall of 1930 in order to get work started early, in the interests of unemployment relief and to stimulate general business activity. As a result of this effort, bids were advertised in December which was six months earlier than the date set in an announcement several weeks before. This indicates the speed at which the work was pushed and accounts for the fact that many minor details could not be completed at the time specifications were released. In addition to the rushing of specifications for the main structure, work was advanced rapidly on the government's preparatory field work, including the planning of the town and the highway and railroad from the town site to the canyon.

Bids on the main contract for the dam were opened March 4, 1931. Three regular bids were received. Six Companies Inc., San Francisco, a company composed of six veteran Western contracting firms, was the low bidder, and the contract was officially awarded April 20. The organization and activities of the contracting group are outlined in a following article.

Early hardships

With the necessity of moving the major contract ahead, because of emergency conditions, the work of the bureau in preparing plans and carrying out preliminaries for a project of such magnitude was made distinctly difficult. Under ordinary procedure the major contract would not have been let until a year or more later; prior to the award, design studies would have continued, the town would have been built and prepared for occupancy, and the principal technical questions would have been decided. The accelerated schedule of the entire project moved the construction program up to overlap with preliminary work, and the result was hardship and strain on both organizations.

It was impossible to carry out the original plan to have the town built and properly equipped and transportation facilities to the site completed before the contractor would start on the work. The first men of the contractor's force began work weeks before the contract was signed. At that time the town site (later named Boulder City) was an expanse of raw desert at the end of the railroad branch. Work was under way on the government highway and railroad to the canyon, the laying out of the town site and the start on the water-supply system. The contractor began at once to open up roads into the gorge to get at the diversion-tunnel portals. Activities at this period were reported in *ENR*, May 28, 1931, p. 895. Power was available at the site on June 13, 1931.

The preliminary work comprising the first stage of construction operations is now completed with the diversion of the river. Many features of these operations have been presented in past issues of *Engineering News-Record*. This issue rounds out these features and presents the future construction program. Hoover Dam is now entering the second stage of construction—foundation operations—in preparation for the final huge task of dam building accompanied by powerhouse penstock and intake work.

* * *

The decade of development and effort reviewed above set the stage for last month's crowning work of closing the river and diverting the waters through two of the tunnels. Before considering in detail what is taking place at Black Canyon today, it is well to recall the situation that confronted the Bureau of Reclamation and later the contractor in getting the huge project into the bidding and construction stages. This is reviewed in the following article which includes also an account of the manner in which the contractor, a special company made up of six separate firms, organized to carry on.

Bidding and Planning for the Construction Battle

Difficulties and risks involved in building the world's highest dam—Organization of contractor's forces and getting the work started

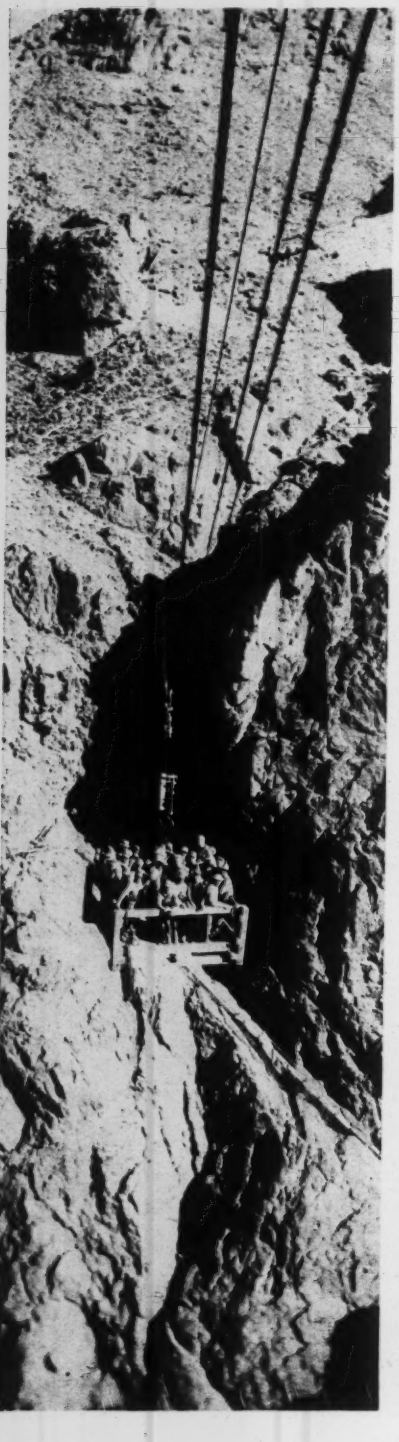
TWO YEARS AGO the construction industry was eagerly awaiting the call to bids for a record-breaking contract to build the biggest dam in the world. Today the successful bidder, Six Companies, Inc., has the work a year ahead of schedule and has diverted the Colorado River from the site. Beginning with the preparation of plans and specifications, the work on Hoover Dam has been a rush job, with progress at an ever-accelerated rate.

Within two weeks after the opening of bids and determination of low bidder, the contractor had opened a field office and had put his preliminary work under way, although the contract had not been signed and even the constitutionality of the Boulder Dam Act itself was still awaiting decision by the Supreme Court. By April 20, 1931, when the contract was formally executed and official word was given to begin work, scores of men were already on the

Fig. 5—Building the road down the Nevada side of the gorge to reach the lower portals of the tunnels was a major job for the contractor in the early stages of the work.

job, temporary camps were in operation, and equipment and crews were busily at work opening up roads to the diversion-tunnel portals. Four weeks later, when the United States Supreme Court affirmed the validity of the act (May 18), preliminary tunneling operations were in progress, highways and a railroad were being pushed into the canyon, and permanent camp buildings were well started.

Fig. 6—A cableway swung across the canyon for transporting workmen to the Arizona side saved a 6-mile trip that would have been necessary for the land-water route.



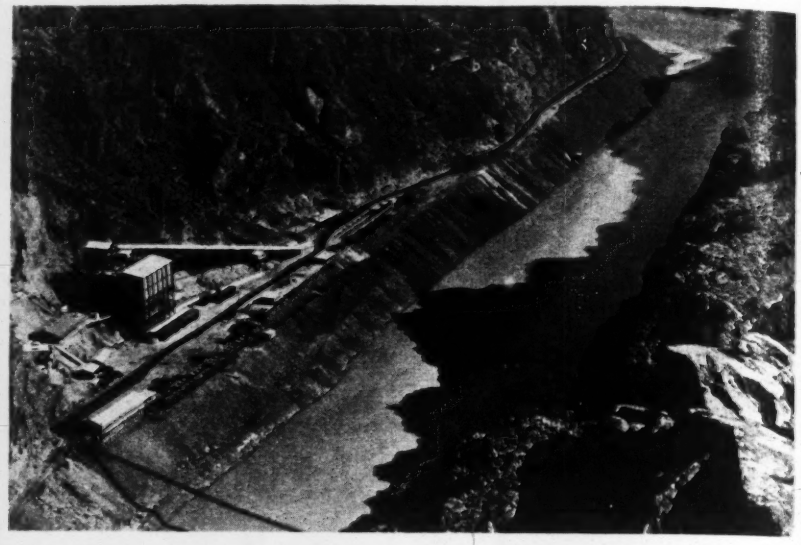


Fig. 7—Millions of yards of concrete will be manufactured at this ultra-modern mixing plant located on the Nevada side upstream from the diversion tunnels. Aggregates and cement are delivered by rail.

The speed of attack that was evident in these early days of the undertaking has never slacked. As new phases of the work extended the field of activity and steadily increased the volume of work, the same drive for rapid progress continued. Even the serious difficulties of the first session were not allowed to delay the work; though the contractor had to contend with the heat of a record-breaking summer and the absence of living and supply facilities at Boulder City, he kept his forces going at increasing pace, favored by the unusually low floodflow of the river and by the fact that construction conditions made it possible to recruit an organization of exceptional quality.

Appraising the plans

About two months were available for estimating the job and preparing bids between Jan. 10, 1931, when specifications were available for distribution, and March 4, when bids were opened. The call for bids had been pushed months ahead of the time originally contemplated, in order to stimulate construction and increase employment. While the general features of the development, its location and climatic conditions had been known and studied by interested contractors for some time prior to the actual announcement, yet the actual bid calculations could not be begun until the plans and specifications for the project were issued.

Up to that time it had been expected that the work would be divided into several sections for separate bids and contracts. But the Bureau of Reclamation finally decided that complete coordination of the construction operations was necessary. Tunnel plant and progress, for example, would vitally affect the river-closure operations, and these in turn the foundation work, and so on through the whole undertaking. If separate contractors were in charge, delays and friction might be apprehended. Hence the decision to let a contract for the whole work as a unit. This decision was important because it emphasized questions of finance and organization.

An important provision relating to financing was that which fixed the bid bond at $2,000,000 and the construction surety bond at $5,000,000. On an estimated total value of about $50,000,000 for the contract this necessitated a bid bond of 4 per cent and a surety bond of 10 per cent. The size of bond required and the clause fixing the damages for failure to complete construction on

ORGANIZATION OF SIX COMPANIES INC. —BUILDER OF HOOVER DAM

Member Companies:
- W. A. Bechtel Co. and H. J. Kaiser, San Francisco
- Utah Construction Co., Ogden
- MacDonald & Kahn Co., San Francisco
- J. F. Shea Co., Portland, Ore.
- Pacific Bridge Co., Portland, Ore.
- Morrison-Knudsen Co., Boise, Idaho

Officers:
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- E. O. Wattis, vice-president
- H. W. Morrison, vice-president
- Felix Kahn, treasurer
- Charles A. Shea, secretary
- K. K. Bechtel, assistant secretary and treasurer

Executive Committee:
- H. J. Kaiser, chairman
- Felix Kahn
- S. D. Bechtel
- Charles A. Shea

Field Organization:
- Charles A. Shea, director of construction
- Frank T. Crowe, general manager of construction
- A. H. Ayers, chief engineer
- Bernard Williams, assistant general superintendent
- T. M. Price, in charge of aggregate production
- J. Perry Yates, office and designing engineer
- B. W. Goodenough, field engineer
- C. J. Seymour, safety engineer

schedule at $3,000 per day indicate the magnitude of the financing required for bidding.

One outstanding provision of the specifications was the acceptance by the government of responsibility for flood control and resulting damages, with the exception of the contractor's equipment, after satisfactory completion and acceptance of the diversion system consisting of four 50-ft. tunnels and permanent up and downstream cofferdams. This provision relieved the successful bidder of responsibility for flood control and damages during the period of foundation work and the early stages of dam construction, which would normally extend over a period of more than two flood seasons, but did not change the contracting risks of taking care of floodflow during the two seasons required for driving and lining the diversion tunnels.

The contractor had to assume the risk of changing labor rates over a seven-year period, but all materials and equipment entering into permanent features of the project are furnished by the government. This latter provision was desirable on a job of this magnitude, especially as most of these items would not be purchased until long after the contract was signed. Indeed, design of much of the permanent equipment and accessories was in only the preliminary stage at the time of writing specifications, and some materials, such as cement, had not yet been definitely decided upon.

Engineering features and uncertainties

The unprecedented requirement of a cooling system of pipes throughout the mass of concrete composing the body of the great dam necessitated estimates and plans for a new type of construction operation. The specifications required a plant with all accessories sufficient to reduce the temperature of 2,100 gal. of water per minute from 47 to 40 deg. F. It was estimated that the amount of heat to be removed was about 700 B.t.u. per degree per yard of concrete. These estimates and calculations, being prepared prior to the settling of many questions relating to quality of cement and concrete (decided only recently, in October, 1932), obviously were subject to later modification, which introduced a large bidding uncertainty.

Other uncertainties arose from the probability that the exceptional character of the structure would lead to changes in plan during the course of the work—changes of minor kind when compared with the magnitude of the entire work, but individually large. In fact, substantial changes have been made in the design since the original specifications were prepared and contract awarded. Re-study of the spillway design resulted in revised plans that reduced the estimated yardage of excavation from slightly more than 1,000,000 cu.yd. to less than 600,000 cu.yd. The inclined tramway to the power plant provided in the original plans was later changed to a 150-ton cableway. A decision to place steel lining in the penstock tunnels introduced another important modification in the original specifications. These features are mentioned to indicate the continued evolution of design since the bidding was in progress.

A well-recognized problem in early construction operations was the complete lack of facilities at Boulder City, where, according to specifications, 80 per cent of the construction force was to be housed. Although the plan for Boulder City development was completed, work on the water-supply system was only started and street work had not even been contracted when bids were opened. This meant that during the first summer living conditions would be temporary and inadequate, awaiting the completion of facilities at Boulder City.

Flood uncertainties had profound bearing not only on the bidding but on the progress of the early stages of the work. In so strange and erratic a river as the Colorado these uncertainties are far larger than in other streams. River-flow data contained in the specifications indicated that the nearest available upstream record was the hydrograph for the river above the inflow from Bright Angel Creek, about 275 miles upstream from the dam site. At this station the average annual runoff from 1923 to 1929 was 15,627,000 acre-ft. In general it was known that low-flow conditions extend from August or September to April, that the flood season begins in April, that the peak is reached in May or June, and that the river volume declines the following two months. However, there is no regularity in the yearly records, and flash floods in September of 1923 and 1927 reached a peak of 100,000 sec.-ft. The normal flood peak for these years of record was slightly more than 100,000 sec.-ft., and the low flow averaged less than 10,000 sec.-ft. A flood of 100,000 sec.-ft. at the dam site raises the water level about 20 ft. above low-flow stage. Thus, it was evident that during a large part of the year interruption by floods might be expected.

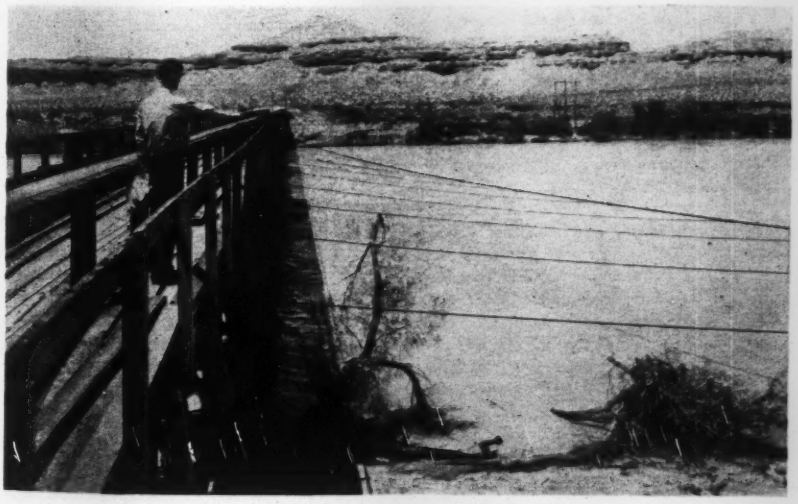


Fig. 8—Early plans of the contractor to transport gravel across the river by a belt-conveyor system from the Arizona deposits was abandoned in favor of this timber trestle that allows gravel trains to be loaded at the pits. Although this bridge was expected to be carried away by floods, it has successfully stood up so far during high-water flows, with the help of anchor cables shown here.

Six contractors join

Three bids were submitted for building Hoover Dam. In the case of each of these, as well as several prospective bids, the bidder was a group of contracting organizations. Such a plan was important from the standpoint of financing, and also had the particular advantage of combining groups with experience and personnel for carrying on construction operations of great size and varied kind.

Soon after the bids were called, certain contracting firms, who together later received the contract under the name of Six Companies, Inc., became interested in the job. A syndicate form of organization was proposed, and the details were gradually evolved. Members of the group had performed all of the various types of construction work required for this undertaking and also had had experience in working together in smaller groups on former contracts. The final details of arranging for unified field investigation, estimating and financing were concluded only about two weeks before bids were opened.

Participation in the organization is in accordance with the stock owned, and no one member company controls a majority. All the member companies are represented on the board of directors, which is the final authority in carry-

ing on the work. Since all members of the group are of long standing in the field of Western engineering construction, a large and experienced personnel was available from which could be selected individuals particularly suited to manage and direct various parts of the work. The organization was so arranged that it would not affect the individual operations of member companies, each of which continues to operate independently on other work. An executive committee is provided which extends authority to a resident member of the board of directors on the work and to the general manager of construction. The organizational set-up is more complex than that found in ordinary contracting operations, but it functions in much the same manner.

Starting work in Black Canyon

Immediately after the award of the contract and before the final signing of the agreement, headquarters had been established in Las Vegas, and preliminary work was under way on surveys for highways, railroad lines and temporary camps. Permanent camp buildings were started within a few weeks on the site of Boulder City, although the first ones were temporarily erected on skids, awaiting the final survey.

Down at the mouth of the canyon a temporary camp was constructed, which later grew into the permanent river camp, housing several hundred men. First actual construction work in the canyon was the blasting of a road through solid rock to reach the upstream portals of the diversion tunnels on the Nevada side. In the meantime, by means of boat and barge transportation into the canyon, adits were opened up on both sides of the canyon to tap the four diversion tunnels and provide eight additional working faces.

Within six months the contractor had 3,000 men at work and had in large measure completed the permanent housing and feeding facilities for the construction army. During this same period the government had finished the major facilities in Boulder City, and the town had become a modern community with all municipal conveniences. During the past year the work has expanded and progressed rapidly, reaching a significant point when the river was diverted from the site last month, marking the completion of the first stage of the project.

* * *

Not only were the unprecedented difficulties in getting work started overcome, but the success of the engineer's and contractor's plans for the first stage of construction has been so marked as to place the work an entire year ahead of schedule, after only twenty months of activity. Closing of the river, accomplished on Nov. 13 and 14, the climax of preliminary operations, is next described.

Huge Blast Turns River Into Diversion Tunnels

Historic event in Colorado River program occurred Nov. 13—Blowing out of barriers at tunnel portals was followed by rapid damming of channel by truck-dumping

RUSHING into the two cavernous diversion tunnels on the Arizona side of the canyon after the blasting of the portal cofferdams, the Colorado River was turned from its Black Canyon channel on Nov. 13, 1932. The event was the most significant since the project was started about a year and a half ago, and it marks the close of the first major division of the construction program. Now the dam site is open for coming phases of foundation preparation and concrete placing. Diversion of the river in the 1932 low-flow season places the construction program definitely one year ahead of schedule.

On the morning of Nov. 13 the two 50-ft. diameter Arizona diversion tunnels were ready. The channels at their outlets had been cleaned sufficiently to carry the water diverted through the tunnels, the spoil banks at the inlets had been cleared below water surface, and the temporary cofferdam at the inlet of No. 3 had been blasted below the top of the foundation for the trashrack structure. At 11:30 a.m. blasts were set off in the temporary cofferdam at

Fig. 9 (above)—One hour before blasting out the barriers in front of the two Arizona tunnel portals, the river is placidly flowing by 11 ft. above invert level.

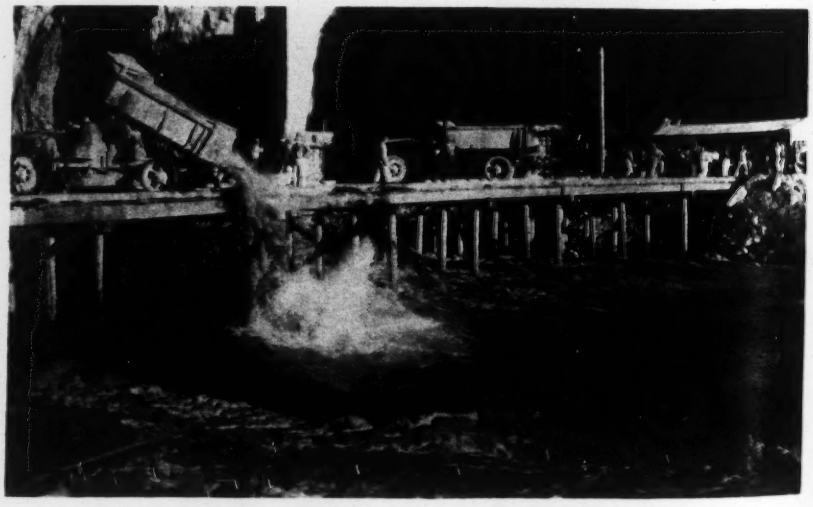


Fig. 10 (below)—Two hours after the blast trucks are rapidly filling in the channel. The river was entirely closed off early the next morning.

the inlet of tunnel No. 4 and at the spoil banks at the outlets of both tunnels, and water from the Colorado River first flowed unimpeded through a tunnel.

Immediately rock-dumping was started by trucks from a timber trestle bridge below the portals to provide a temporary dam across the channel and to complete diversion. The dam of rock and earthfill was built up rapidly as the loaded trucks rolled out on the trestle, were dumped and reloaded. On into the night the work continued, and by the next morning diversion had been completed. During this period the rock barrier that forms a part of the downstream cofferdam was started, and six hours after the upstream diversion had been effected the closure was finished at the lower end.

Two months before actual river diversion, work had begun on the permanent upstream cofferdam. Flow in the river during September dropped to less than 6,000 sec.-ft.; and although flash floods during the early fall are always a possibility, the contractor confined the stream to a 90-ft. channel by means of a rock and earth dike, to permit the beginning of foundation excavation for the permanent upstream cofferdam. By end-dump methods this fill was constructed down the center of the river channel a distance of about 700 ft. and then turned in to connect with the Nevada wall of the canyon inclosing about half the site of the cofferdam. The area was soon pumped down, and shovels and drag lines were brought in to remove the river silt and gravel. Excavated material was trucked a few hundred yards to the terminal of the railroad line in the canyon, where it was transferred to trains for removal. Operations during this stage of the work were described in the issue of Nov. 24, 1932, p. 622.

* * *

Provision having been made for winter's low-water flows to be diverted through two tunnels, two great earth dams will now be thrown across the river as permanent cofferdams. Under their protection the foundation of the dam will be excavated. In the next article the design and construction of these cofferdams is presented.

Permanent Cofferdams to Be Large Earth-Rock Fills

Upstream structure, 98 ft. high with concrete facing, will be completed in February—Design and construction methods described—Plans for unwatering outlined

WITH THE Colorado River turned into two diversion tunnels, construction activity has concentrated on the building of the permanent cofferdams which will complete the diversion program and make the Hoover Dam site available for subsequent operations. The two barriers sealing off the dam site are impressive structures in themselves; the upper one is to be 98 ft. high and will contain 568,000 cu.yd. of earthfill and 157,000 cu.yd. of rock, the upstream slope to be faced with a concrete slab. The construction schedule provides for the completion of the upper dam by the end of next February, which is about 60 days before the beginning of the usual spring rise in the river. In the meantime, the contractor will carry forward the construction of the downstream rock barrier and cofferdam, the other unit in the permanent diversion program. Unwatering the dam site will be accomplished by a 187-ft. shaft and drift reaching under the river channel and equipped with pumps discharging into a diversion tunnel.

River diversion for Hoover Dam is of unusual significance not only because of the magnitude of the project but also because it was completed twenty months after formal award of the contract, placing the job nearly a year ahead of schedule. The preparation for bypassing the river undoubtedly constituted the largest and the most costly diversion-tunnel program ever attempted. The driving of 16,000 ft. of 56-ft.-diameter tunnel and the subsequent placing of a 3-ft. lining, which involved over 300,000 cu.yd. of concrete, are indicative of the scope of the operations on the site.

Cofferdam Design — The permanent upstream cofferdam is a rolled earthfill structure with a reinforced-concrete upstream paving and a rock blanket on the downstream slope. The dam is located 810 ft. upstream from the axis of the main dam and about 600 ft. below the diversion tunnel portals. The dam will have a foundation on consolidated sand, gravel and boulders after excavation of 250,000 cu.yd. of river silt and loose deposit. A row of steel sheetpiling along the upstream toe connects with the concrete facing slab.

The structure is 98 ft. high from base to crest (El. 720), rising 30 ft. above the top of the diversion tunnels. The upstream slope is 3:1 and the downstream slope is 4:1. At the elevation of the base of the cofferdam a berm 70 ft. wide is left and excavation to bedrock for the dam proper will be carried at a slope of 2:1 and subsequently faced with 20 ft. of riprap. High-water level against this dam for a flood discharge of 200,000 sec.-ft. is at El. 707, or 13 ft. below the crest elevation.

Paving on the upstream face consists

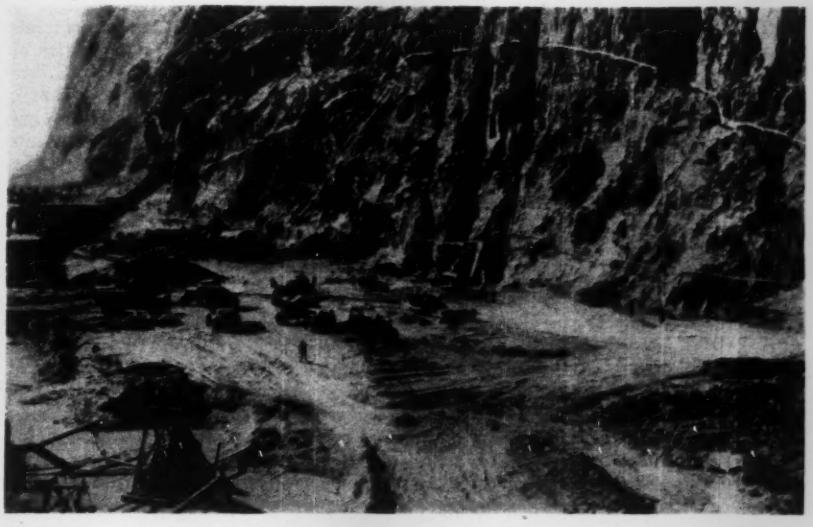


Fig. 11—On the Nevada side of the upstream cofferdam site filling is actively under way in the upstream section, while excavation of river deposit to the consolidated gravel foundation is still in progress downstream, as seen in the background. Along the canyon wall can be seen the three percolation stops of concrete, which extend a minimum of 5 ft. out into the fill. The white line on the rock wall indicates the contact of the cofferdam and the side of the Colorado River gorge.

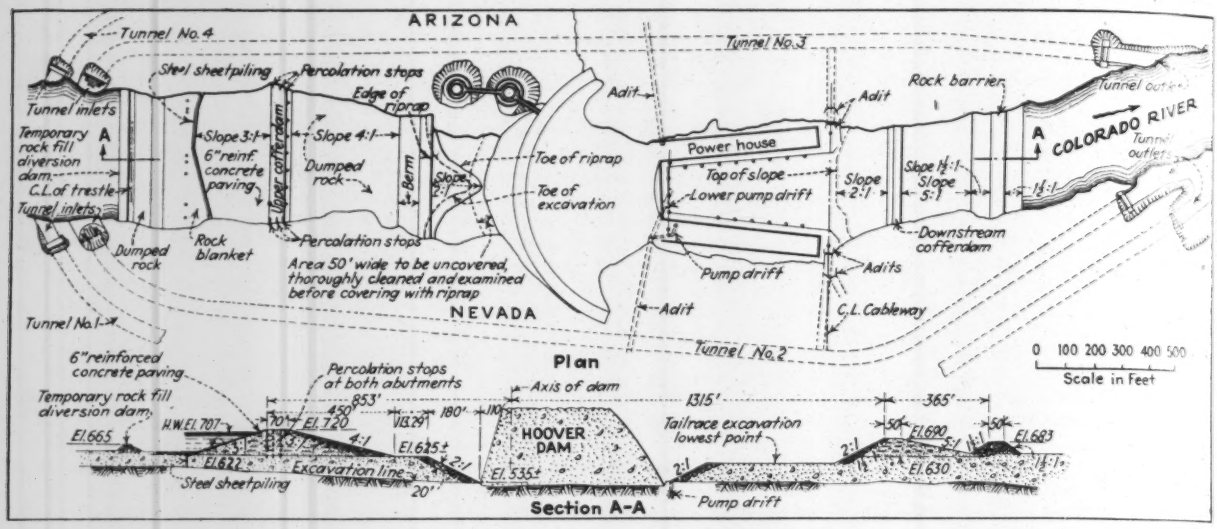


Fig. 12—A cofferdam system involving structures of massive proportions and permanent construction provides for the unwatering of the Hoover Dam site.

of a 6-in. reinforced concrete slab with ⅝-in. round bars on 15-in. centers in both directions. The reinforcing is continuous through the construction joints, which extend up and down the face on 16-ft. centers. The slab extends down to and connects with a line of steel sheetpiling driven to bedrock along the upstream toe. Backing for this slab consists of a 3-ft. layer of dumped riprap with the voids sluiced full of silt and clay. The connection between the slab and the cutoff piling includes a sheet-rubber water stop on the inside of the joint and a backfilling of puddled clay under a 5-ft. thickness of dumped rock. Also, along the joint of the paving slab and the canyon walls a V-shaped continuous sheet-rubber water stop is provided. Three percolation stops, consisting of reinforced-concrete walls, project at right angles a minimum of 5 ft. from each canyon wall (Fig. 11).

The downstream permanent cofferdam system consists of a rolled earthfill structure, 60 ft. high, protected on the downstream side by a rock barrier 53 ft. high. The crest of the lower cofferdam is 1,340 ft. downstream from the axis of the Hoover Dam (Fig. 12), and the crest of the rock barrier is an additional 365 ft. downstream, although the slopes of the two intersect. This dam is also founded on consolidated material of sand, gravel and cobbles, after removal of loose riverbed material. The rock barrier has a crest width of 50 ft. and 1½:1 side slopes. The earth dam has a crest width of 50 ft. at El. 690, with a downstream slope (the water side) of 5:1 and an upstream slope of 2:1. The latter slope, toward the dam site, is protected by a thick rock blanket. From the toe of this slope a 400-ft. length of river channel will be left as berm, and the excavation at the actual site will be carried down on a slope of 2:1 through the gravel to bedrock.

No cutoff system is provided in the downstream cofferdam, although foundation is excavated into consolidated material. The lower rock barrier is provided primarily to protect the main earth dam from the backwash of the river during flood discharge from the diversion tunnels, but it also served as a convenient preliminary unit for the contractor's operation on this lower cofferdam system.

Construction Methods—Gravel-fill material for the upstream dam is being brought by train about 3 miles from the flat area at the lower end of Hemenway Wash. An area of about 25 acres was stripped, and a loop track was built to facilitate train movement. The earth and gravel is being excavated by electric shovel and loaded directly into the 30-yd. side-dump cars. Double-track railroad operation is provided as far as the concrete mixing plant, and the line has heavy traffic as it is also used in transporting aggregate and cement into the canyon as well as for bringing all excavated material out. Trains haul excavated material out of the canyon and return with loaded cars of fill material. Gravel is dumped from trains and reloaded by shovels into trucks for placing in the dam. According to specifications, the fill is being placed in 12-in. layers, sprinkled and rolled to compaction.

The opening up of half the cofferdam site prior to the completion of river diversion permitted excavation to be well advanced in this area, and backfilling started before the river was diverted. At the present time fill is being placed in the Nevada half of the river channel, and excavation is going forward rapidly in the other half of the channel, following completion of river diversion.

Specifications required the steel sheetpiling for the cutoff to be driven to bedrock, lengths from 40 ft. near the abutments to 50 ft. at mid-channel being needed. On the Nevada side a sloughing-off of the cliff in times past had filled the river with large blocks of rock and boulders. Difficulty in driving sheeting through this material forced the contractor to excavate a trench to solid rock, then pour a seal of concrete in which the sheetpiles were set. Driving of piles for the remainder of the cutoff is now in progress.

With completion of the cutoff and fill, work will be extended to the rock backing and concrete paving and the rock blanket on the downstream face, which will complete the structure. The present program provides for completion of this permanent cofferdam by March 1 and the downstream structures by April 1, 1933. During the winter months the river flow averages about 5,000 sec.-ft., and flood danger is at a minimum up to February. By the beginning of the 1933 floodflow season the lining and grouting operations will have been completed in the Nevada tunnels and all four diversion tunnels will be available for flood discharge. The peak floods of the past several seasons have slightly exceeded 100,000 sec.-ft. as compared to the 200,000 sec.-ft. estimated flood that was used in the design of the tunnels and cofferdams.

Unwatering the Site—To unwater the half-mile section of the river channel between the up and downstream permanent cofferdams and to drain the actual dam site and hold down possible seepage, the contractor has driven a pump drift under the river channel from a shaft sunk from the old adit to the Nevada diversion tunnels. The location of this unwatering system is indicated in Fig. 12. The adit was driven during the preliminary stage of tunneling to open up additional faces near the middle of the diversion tunnels.

From this adit a 187-ft. shaft was sunk and enlarged at the bottom to provide for a sump and pumping equipment. From this pumping chamber a drift was excavated through solid rock under the river channel and then raised and prepared for blowing through after the river was diverted. The location is at the center of streambed about 50 ft. downstream from the downstream toe of the dam. As soon as the main unwatering is completed a further tunnel will be driven through the cemented gravel along the bedrock line to act as a drain and to collect seepage. The pump system is located in the bottom of the shaft to insure priming and will have a capacity of 8,000 g.p.m., lifting the water into the No. 2 diversion tunnel. More pumping capacity may be provided at any time, if needed.

* * *

Contemplation of the completion of the cofferdams next February leads directly to consideration of the design of the Hoover Dam itself. Congress designated the Colorado River Board of Review—the Sibert board—whose approval of plans is required before the dam may be built. In the light of what the tunnel-driving taught about the rock and what intensive study and experiment showed as to the dam and its appurtenances this board gave final approval on Nov. 19, 1932. Its report comprises the subject of the following article.

Colorado River Board Approves Design of Dam

Few changes made in plan for structure since contract was let—Dam shifted 10 ft. toward Arizona side—Other features of project considered

FINAL APPROVAL of the design of Hoover Dam was given Nov. 19 by the Colorado River Board, appointed in 1928 by President Coolidge to report on the engineering aspects of the entire project. Though analysis of the design and investigation of the site have been carried on continuously since the bids were called for, few changes have been made in the structure since the contract drawings were prepared. The principal changes include a shift of the dam 10 ft. toward the Arizona side and the addition of concrete fillets at the abutments on the downstream side.

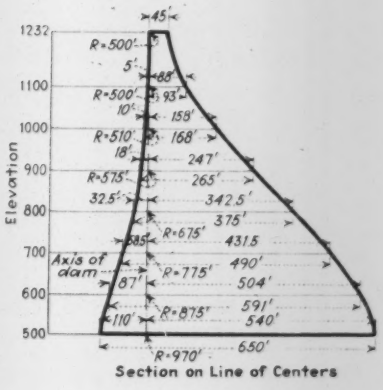
Following is an abstract of the report submitted Nov. 19 by the board to the Secretary of the Interior. The report was signed by Daniel W. Mead, acting chairman since the resignation of General Wm. L. Sibert, Charles P. Berkey, secretary, Warren J. Mead and Robert Ridgway.

Ready to start dam

The board was called together for final consideration of the general plan and cross-section of the dam. The contractor will soon be ready to start abutment excavations, and definite approval of the design of the dam is needed so that these excavations can be staked. Several additional matters bearing only indirectly on the design of the dam proper, but vitally pertinent to certain subordinate work and to the success of the project, are also treated in this report. Particular attention was given to the relation of the natural features of the site to questions before the board, in light of information now so well disclosed by the work in progress. Both the natural physical conditions at the site and the general conduct and execution of the work appear to the board as thoroughly satisfactory.

Additional time has been spent with the engineers in charge of design and research in Denver. The board is impressed with the progress made in these studies and with the thoroughness, care and ingenuity with which these investigations are carried on.

Fig. 13—General plan and cross-section of Hoover Dam as approved by Colorado River Board. Fillets have been added to the abutments by varying the radii of the concentric arches.



The board approves the plan and maximum section of the dam as shown in drawing No. 45-D-2080 of Study No. 37, dated Sept. 22, 1932. (Fig. 13). It is understood that such design is subject to possible minor changes, such as the substitution of a straight instead of a curved downstream profile in the lower part of the dam, and of such additional fillets on the upstream profile and at the arch abutments as continuing studies of these features may indicate to be advisable.

Additional problems

Abutment Excavation—It is obvious that the best possible seating of the dam against the canyon walls is essential and that every precaution must be taken to attain that end. The rock of the abutments is of such excellent quality and so much superior in strength to the concrete which would replace any excess removal that excavation should be limited to the requirements of proper abutment stress design.

Tunnels Disclose Information—Exploration of the side walls of the canyon back of the abutments of the dam has been accomplished by the driving of the four 50-ft. diversion tunnels. The rock condition and quality in detail have been well shown. It is now a matter of record that the rock behavior during tunneling operations has been exceptionally good. Only in rock formations of the highest quality can tunneling on such a scale be done in safety. In general it is to be expected in driving large tunnels that zones of weakened rock requiring roof support will be encountered, that falls of rock from the roof will occur, and that there will be a certain amount of overbreak due to the weakened condition of the rock. Here, however, in 16,000 ft. of finished bore, not a single place required support, and the excavation was carried remarkably true to the specified cross-sections. No element of weakness or of questionable behavior was developed in the four diversion tunnels around and back of the abutments of the dam.

The thoroughly dependable character

of the walls of the canyon, a matter wholly of judgment and interpretation when this site was selected, is now fully proven. There is no doubt of the satisfactory quality and condition of the rock formation that is to support and hold the dam.

Tunnel No. 1 Outlet—The outlet portal of spillway tunnel No. 1 is of necessity so located as to require a deep side cut more than 600 ft. long, the wall of which turns slightly toward the river. For part of this distance the excavation cuts a zone of fractured rock not occurring elsewhere in the immediate vicinity of the dam site. The rock slope of the excavation through this section is so unstable as to appear to require protection from heavy spillway discharge to obviate the hazard of undercutting the canyon wall. This could be avoided by extending a concrete conduit downstream from the portal 400 ft. or more, but the cost would be excessive. It is believed that adequate protection can be afforded also by a properly designed concrete wall. Some such provision should be made if experience during the construction period (while the tunnel is used for diversion of the river flow) indicates the necessity of it.

Riverbed exposed

In the portion of the riverbed exposed in the westerly half of the upper cofferdam, now under construction, after the removal of some 20 ft. or more of silt and loose gravel, a fairly uniform bed of compact and well-assorted gravel was encountered, furnishing better foundation for this structure than was originally anticipated. The material being placed in the cofferdam, when wetted and properly rolled in place, is a dense, fairly impervious mass well suited to the purpose. The steel sheeting so far, as placed in its final position at the time of the visit of the board, had been set in a concrete footing in open excavation to bedrock and backfilled by puddle on both sides. The compact and relatively impervious and stable nature of the river fill, as disclosed in the excavations, and the manner in which construction work is being carried on promise a thoroughly successful structure for protection of the work of excavation and the construction of the lower portion of the main dam. No difficulties are anticipated provided that no unusual flood occurs during the early stages of the cofferdam construction.

River Fill and Its Behavior—One of the elements of greatest uncertainty in the beginning and through the whole period of development to very recent date has been the river fill. Normally the gorge is filled to a depth of more than 100 ft. with sand, gravel and boulders, the exact physical character and behavior of which could not be predicted. It was realized from the beginning that great difficulty and expense might have to be met if this material should prove to be loose and pervious and inclined to slump and ravel when the excavation for the dam is made, whereas all these difficulties would be greatly simplified if the river fill should prove to be stable and comparatively tight.

Excavation made for the upper cofferdam has exposed this riverbed material to a depth of more than 30 ft. Its quality with respect to physical structure and stability and its relatively low permeability are both more satisfactory than originally anticipated. The material exposed at the site of the cofferdam furnishes a suitable foundation for that structure, standing well in the excavation walls and yielding surprisingly little water.

This is new and very important information. There is good reason to believe that similar conditions will be encountered in the excavation for the main dam; and although much variability in character of material as well as increase of seepage with increase of head is to be expected in a deposit of this kind and of such great depth, there is now little doubt about its general stability and comparative freedom from costly and dangerous behavior.

The excavation to be made for the main dam will furnish a unique opportunity to determine the structural detail of the river fill of this great gorge, of which advantage should be taken to make a complete descriptive and graphic record. Such a record will be of use not only in case of additional developments on the Colorado River but will be of future value on other rivers of similar history.

Spillway geology and treatment

Sufficient variation in quality of foundation rock has been encountered in both the Nevada and the Arizona spillway excavations to warrant making special provision for the foundation of the weirs and preventing undesirable water seepage. In both spillways foundation of the weir will be excavated at least as low as the excavation for the spillway channel at those places where broken and porous rock have been disclosed, and there is no doubt of the safety of the structure when adequately grouted and drained.

The Arizona spillway exhibits somewhat special geologic conditions. The so-called spillway breccia is made up of a mixed lot of volcanic debris filling an ancient volcanic vent up through which hot vapors continued to issue for a long time after the accumulation had completely filled the crater and the site had been covered with later deposits. This ground introduces no particular difficulty or danger and affords an adequate foundation for the spillway structures.

Concrete Aggregate—The material as developed in the Arizona gravel deposit is admirably suited for the concrete aggregate, and it is doubtful if material of a better quality and grading for the purpose could be found. The stripping of the deposit is light, and the material is so well graded that there is little waste. There appears to be a sufficient quantity for all demands.

Observation tunnel

A tunnel intended to serve as a drainage sump for the foundation excavation has been driven by the contractor beneath the floor of the gorge. At the present stage this tunnel does not reach beneath the deepest notch in the floor, and it ends at a point some distance downstream from the toe of the dam. For its original purpose little more may be required, but the usefulness of this tunnel is not confined to its service as a sump.

Already it has added materially to the accuracy of knowledge concerning the quality and condition of the rock floor beneath the dam. It is especially encouraging to note that the tunnel thus far has encountered only sound rock. At the time of the board's inspection this tunnel was inaccessible, but reports indicate that there is virtually no leakage into the tunnel under the river.

The opportunity for obtaining other kinds of information is of greater importance. Advantage should be taken of it to carry a branch tunnel of small cross-section for observation purposes, entirely across the river beneath the toe of the dam. Such a tunnel would explore the remaining portion of the rock beneath the deepest section of the gorge and is fully warranted even for that purpose alone. It would make possible, in addition, a series of important direct observations bearing on matters now necessarily treated wholly on theoretical lines.

Measurements can be taken of the strain conditions now existing in the rock beneath the gorge, and it is desirable that these measurements be continued during and following the construction of the dam. It would give unique opportunity to measure the effect of loading this rock foundation with the dam itself and the additional effect of filling the reservoir.

This is a most important service, and the opportunity should not be lost for gathering whatever data may be furnished by the extraordinary conditions imposed by the new structure at this place. The tunnel should be kept open and should be fitted with whatever devices are necessary to secure reliable data.

* * *

In only twenty months' work a year's time has been gained over the schedule set in advance. The operations by which this was achieved are briefly sketched next, including an account of building the various works necessary to the construction of the project and a review of tunnel-driving.

Review of Preliminary Construction Operations

Railroads, highways, transmission lines, water lines, bridges and a complete city had to be built at the start of the great project—Driving the diversion tunnels

PREPARATIONS for the building of Hoover Dam involved many diversified construction operations of no small magnitude. The dam is located in the deep rocky gorge of Black Canyon, surrounded by mountainous desert wastes, some 30 miles from the nearest community of any size. Climatic conditions of the area are severe, especially in summer, when the temperature rises to almost insufferable heights. Access to the site had to be provided for the millions of tons of supplies and equipment that will be required. Housing facilities had to be provided for a population of 5,000 in the middle of a desert, with utmost consideration given to making the temporary residents as comfortable as possible and to safeguarding their health and conserving their working efficiency. Power, the lifeblood of construction, had to be brought in from faraway sources.

Railroads

Quick and easy access to the site was of prime importance. Consequently, some 59 miles of standard-gage railroad line have been built. Actual construction work on the project began with the building of a 22.7-mile branch line from the main line of the Union Pacific Railroad to the site of Boulder City. This line was commenced on Sept. 17, 1930, and the occasion was marked by appropriate ceremonies, with Secretary Wilbur presiding. This branch line is owned and operated by the Union Pacific. It was built by Merritt-Chapman & Scott Co.

Early in 1931 the railroad line was continued to the rim of Black Canyon, directly above the dam site. This line was built by the government, contract being awarded to the Lewis Construction Co. Its construction involved much heavy grading and five tunnels.

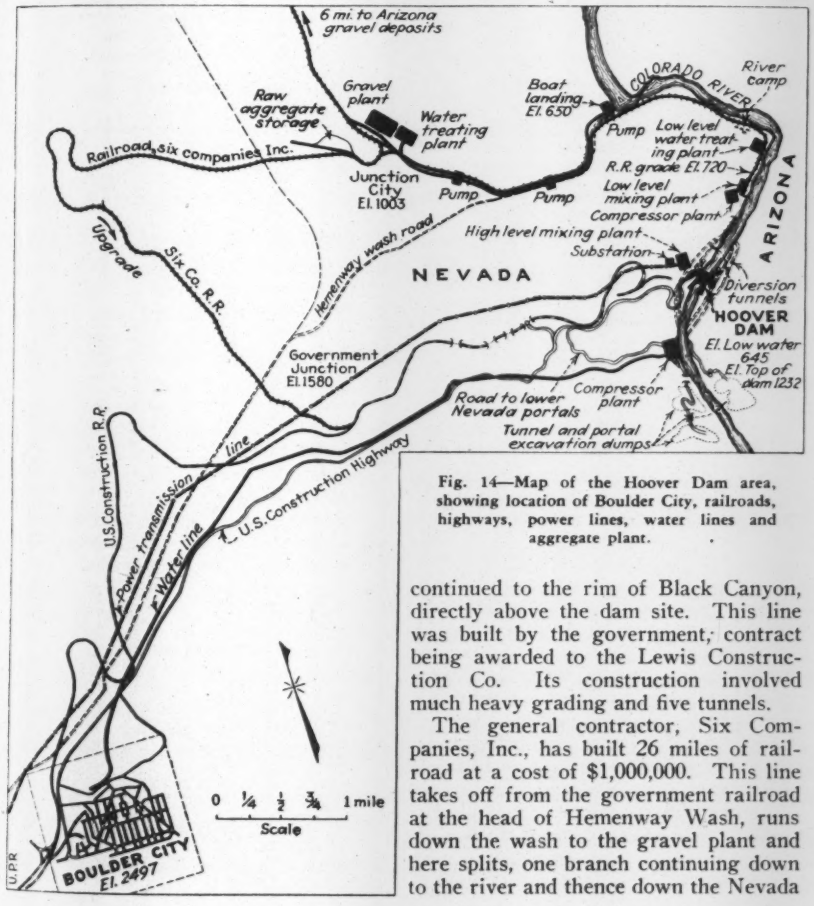


Fig. 14—Map of the Hoover Dam area, showing location of Boulder City, railroads, highways, power lines, water lines and aggregate plant.

The general contractor, Six Companies, Inc., has built 26 miles of railroad at a cost of $1,000,000. This line takes off from the government railroad at the head of Hemenway Wash, runs down the wash to the gravel plant and here splits, one branch continuing down to the river and thence down the Nevada side of the gorge to the dam site. The other branch extends up the river to the Arizona gravel deposits, crossing the river on a timber trestle that is expected to go out in high floods, though it has withstood two floods without being damaged. Two long tunnels, 1,000 and 1,100 ft., were driven through the gorge wall to reach the dam site. A heavy truss bridge is now being built to carry the gorge line over the tops of the upper portals of the Nevada diversion tunnels.

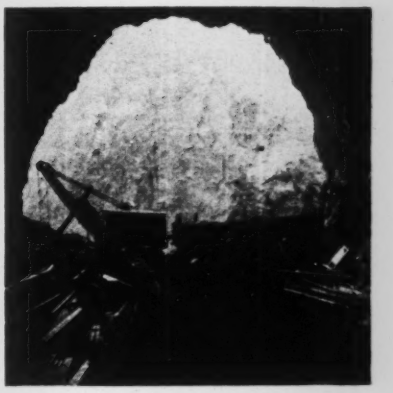


Fig. 15—Four 56-ft. tunnels were driven for a total length of 16,000 ft. to divert the river around the dam site. Later they will be utilized as spillways and penstocks. The shovel shown here is a 4-yd. electric, giving an idea of the huge size of the bores.

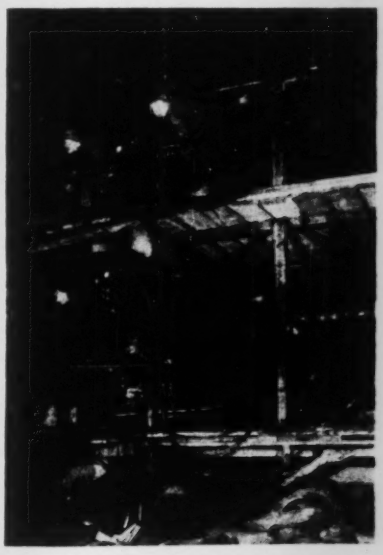


Fig. 16—Truck-mounted carriages handling 30 rock drills each helped to finish diversion-tunnel driving a year ahead of schedule. Here is one of the carriages in action in enlarging work.

Highways

The state of Nevada built a new highway between Las Vegas and Boulder City, a distance of 25 miles. This is the main highway entrance to the Hoover Dam area, though there is a road between Kingman, Ariz., and the dam.

The government built a 7-mile length

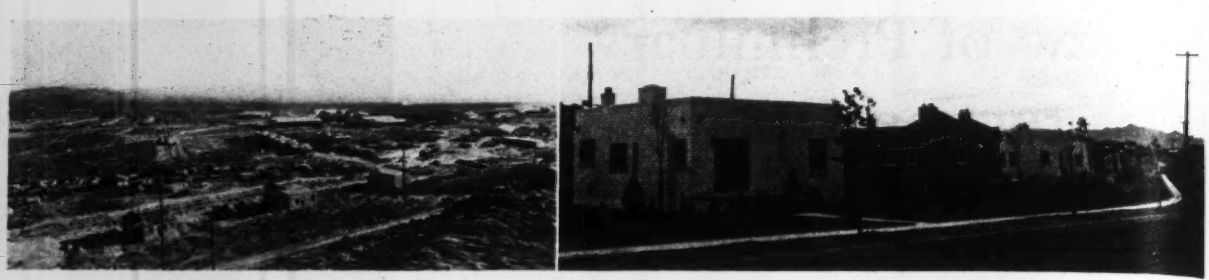


Fig. 17—From a sandy desert waste, as shown on the left, Boulder City has developed into a modern city of the type of homes shown on the right.

of road connecting Boulder City with the dam site, terminating on the Nevada rim of the canyon. This was built by General Construction Co.

From the termination of the government highway Six Companies, Inc., built a road down the side of the canyon to the lower portals of the Nevada diversion tunnels. A timber trestle across the river provided access to the Arizona tunnels. Several miles of highways, all heavy work on steep grades, were built by this firm to provide access to various parts of the work and for disposal of tunnel and spillway spoil.

Transmission line

With the decision to rush the start of construction work, the need of power became urgent. Very little actual construction work in the canyon could be done until an ample supply of power was available. The construction tempo of Hoover Dam was set at the start by the building of 225 miles of transmission line over desert and mountains in 225 days. Power surged through this 132-kv. line on June 13, 1931, two weeks ahead of schedule. The line was built by the Southern Sierras Power Co. as a permanent installation to transmit power from the dam to Southern California after the project is completed.

Auxiliary power lines have been extended from the Southern Sierras substation, near the dam, to various parts of the work. The government built a 7-mile line from the substation to Boulder City.

Boulder City

With the planning of the Hoover Dam project it was apparent that the usual type of construction camp would not be adequate, nor could the workmen be allowed to shift for themselves. Provisions were made for building a complete modern town to accommodate 5,000 population, with the original intention of having it ready before construction work was started. However, the rush to get the job started at the earliest possible moment left no time for the completion of the construction town. Consequently, temporary housing facilities only were available that first searing summer of 1931. At first most of the workmen were housed in a camp at the bottom of the gorge near the dam site. The summer proved to be one of excessive and unusual heat, and working conditions were almost intolerable.

By late fall of that year Boulder City was about complete. The government built substantial houses for its employees. Six Companies erected hundreds of small homes for workmen with families, in addition to dormitory and mess-hall facilities provided for single men. Specifications require that at least 80 per cent of the contractor's workmen reside in Boulder City.

Fig. 19—Numerous bridges were built by the contractor to provide access to the Arizona side of the canyon. A suspension bridge for trucks is shown here. Back of it can be seen one of the earlier suspension catwalks that carried air lines and also was used as a footwalk. In the foreground is the intake of the Boulder City water supply and the preliminary settling tank.

The town was laid out and built, with the exception of the contractor's houses and buildings, by the government. It is fully equipped with paved streets, sewers, electricity and water. The water is pumped from the river against a head of 2,000 ft. Preliminary settling basins are located near the intake, below the dam site, and final treatment works are located at Boulder City.

The government leased land for business purposes to outsiders, controlling the number and type of business firms entering the town. Sims Ely is manager of Boulder City for the government.

Fig. 18—Rough going was encountered in building the government railroad from Boulder City to the top of the canyon on the Nevada side.

Diversion tunnels

The first major construction work under the main contract for construction of the dam was the driving of the four 56-ft. diversion tunnels totaling 16,000 ft. in length. Six Companies, Inc., started tunnel-driving under most trying conditions. Access to the portals was by boat only. Portable compressor outfits were utilized until permanent plants could be brought in.

Phenomenal progress was made in driving the tunnels. Rock conditions were ideal, not a foot of tunnel requiring support. The tunneling system was to drive top-center headings 12x12 ft., followed by enlargement to 56x42 ft., leaving a 14-ft. bottom bench to be removed last. Adits were driven from the canyon to tap the tunnels about midpoint, providing, with the portals, four points of attack in each tunnel. At the lower end of tunnel No. 4, on the Arizona side, the top heading was dispensed with, and a 42x56-ft. face was carried from the portal. This left fifteen faces from which the top headings were driven. The enlargement work was carried on from the portals only. A feature of the enlarging operations was the use of truck-drill carriages, each carrying 30 drills. These were used in both the first enlargement and bottom benchwork. The use of trucks for handling muck was another tunneling innovation.

Future operations

With the virtual completion of the diversion tunnels, work will concentrate on the building of the cofferdams and excavation for the dam. Spillway and intake-tower construction will be carried along at the same time. Penstock installation involves the driving of two new 37-ft. tunnels, tunnels connecting the four penstock tunnels with the power house, and the setting of some 50,000 tons of penstock pipe. Building of the power house and installation of its equipment will closely parallel the construction of the dam.

* * *

Driving of the four 56-ft.-diameter diversion tunnels has created much interest in the engineering and contracting world. Just as spectacular has been the placing of 300,000 cu.yd. of concrete in the 3-ft. thick lining. Design of steel forms of unprecedented size and the placing of concrete at a rate seldom if ever equaled are next described.

Placing 300,000 Yards of Concrete Tunnel Lining

Steel forms and jumbos on rails provide for lining in three operations—Gantry cranes handle concrete for invert and sides—Placement rate exceeds 2,300 cu.yd. per day for a 30-day period

● Lining the 16,000-ft. length of 56-ft. diversion tunnels with a 36-in. shell of concrete constituted one of the major construction tasks in the building of Hoover Dam. The huge bulk of the work alone gave it controlling importance, for the 300,000 cu.yd. of concrete required for the lining is equal to the mass of many a large dam. At the same time unprecedented speed had to be attained in the race to divert the river before the coming spring floods. Despite the complexity of lining operations, placement of concrete exceeded 2,300 cu.yd. per 24 hours for many days—a schedule representing high-pressure work on open mass pouring on dams. The first problem was to plan and design forms and equipment for carrying out such a schedule, and here precedent was distinctly lacking. A form layout capable only of supporting the concrete shell was not sufficient—parts of it had to be rugged enough to reach 50 ft. into the air without distortion. Most important in the speed schedule was the provision of forms that could be quickly set, stripped and moved. And finally, they had to be designed to prevent interference with the concrete trucks. How these design problems were met is told in the first section of the following article. The methods of using the three-section form layout finally adopted, operating procedure, negotiating curves and placing of the concrete is described in the second part. Just as the driving of these gigantic tunnels made drilling and mucking history, the remarkable lining operations have written another new chapter in the annals of tunneling.

* * *

I—*Design of Lining Forms*

DESIGNING the forms and equipment required for lining the 16,000 ft. of 56-ft. diversion tunnels for Hoover Dam involved problems unique, not only for size but even more for scheduled speed of operations. To carry out a construction program which resulted in placing tunnel-lining concrete at rates exceeding 2,500 cu.yd. per day necessitated equipment designed for mobility and rapid centering, convenient handling of concrete in large quantities, adequate strength for supporting unusually heavy masses of fresh concrete, and ample room for transportation.

The original specifications governing the lining of the diversion tunnels were quite general, leaving detail requirements to be covered subsequently. Among the definite requirements in the specifications was an average lining thickness of 36 in. with 24-in. minimum and no payment for concrete placed more than 6 in. outside the line of average thickness. The risk of excessive overbreak was obviously great; the concrete lining for average thickness amounts to 18.5 cu.yd. per running foot. Another definite provision in the specifications required concrete to be placed in horizontal layers in all tunnels where it was possible for men to work behind the forms; obviously this applied to the diversion tunnels. Further, under such conditions concrete was not allowed to drop more than 5 ft. vertically or to move more than 5 ft. horizontally during placement.

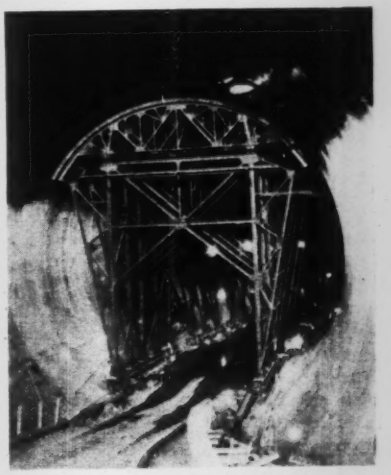


Fig. 20—Arch-form sections towered 50 ft. into the air. Concrete gun carriage is at other end of form assembly. Arch section already poured has been painted with bituminous curing agent. Timber ramp leading over upper-portal arch cofferdam is shown in foreground.

The actual plan of tunnel-lining operations and the type of equipment were problems worked out by the contracting organization, governed by the various engineering requirements such as time required between pours, maximum length of pour, design of joints and other details. These conditions are outlined to indicate the extent of the detailed work required on the part of engineering and contracting forces in preparing this program of unprecedented tunnel-lining operations.

The plan for tunnel lining adopted by

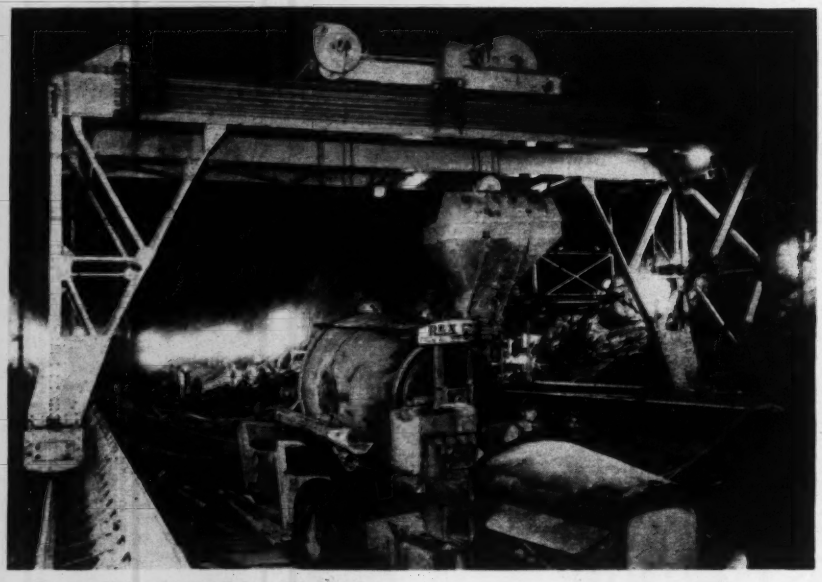


Fig. 21—Units of invert-lining equipment in operation. Four-yard agitator fills two 2-yd. buckets handled by gantry. Screeding and finishing crew are in background. Note rail and edge form at lower left corner.

the contractor provided for placing a 75-deg. invert section as the first step, followed by the pouring of the side walls up to an angle of 55 deg. from the vertical, and finally the pneumatic placing of the 110-deg. arch section. Each of these operations required a complete equipment unit. The original program provided for three sets of forms to permit simultaneous operations in as many tunnels, but subsequently a fourth set was built to allow independent lining operations in each tunnel.

The first step in the lining program involved the building of continuous concrete shelves along the upper edges of the invert section to carry traveler rails. These concrete rail supports were 3 ft. wide on the top by 2 ft. high on the vertical side and were poured directly against the rock behind a timber form. On these shelves were bolted 6x12-in. timber stringers to carry 90-lb. railroad rails, which were set on a gage of 34 ft. 8 in. Extreme care was used in laying out these first supports, as the line and grade of these rails established the base for all succeeding operations. A ½-in. tolerance of line and grade was permitted in the finished lining.

Invert Gantry—On this track operated a structural-steel gantry supporting an electric crane 20 ft. above the invert. This crane (Fig. 21) carried two 5-ton load lines, each operated by a 40-hp. motor to handle the concrete buckets. In addition to the hoist motors, there was a 25-hp. travel motor for propelling the gantry, and a 5-hp. bridge motor. All electrical equipment operated on 440 volts from a 500-ft. length of rubber-covered cable that lay in a timber trough along the wall, allowing a 1,000-ft. run of the gantry.

The gantry frame provided ample clearance for handling concrete buckets and for movement over trucks and finishing operations. In addition to handling concrete, the rig was designed to operate as a general utility piece of equipment in carrying out the first stages of lining operations.

To standardize equipment and provide for a minimum number of parts, the design and specifications for the gantry cranes, motors and hoists were made identical with the cranes used on the side forms.

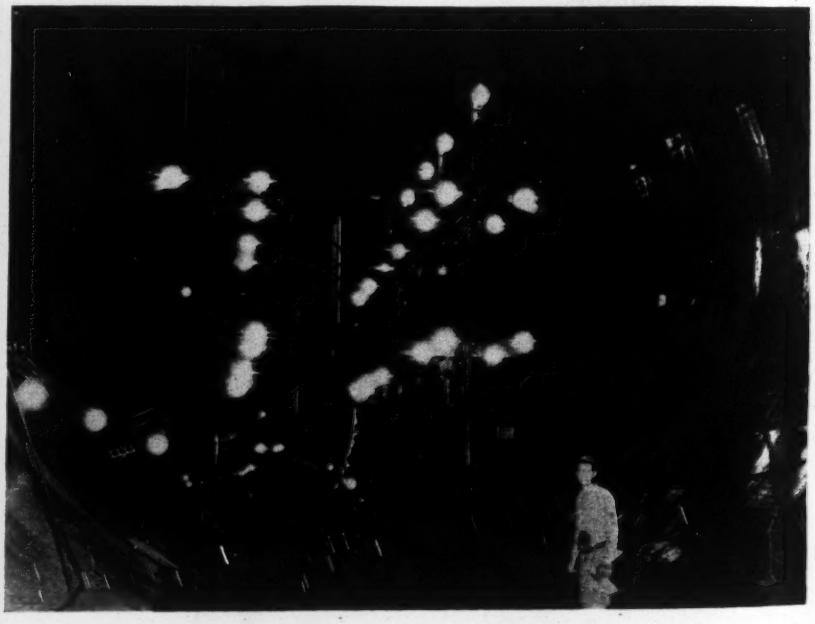
Invert forms consisted of steel side plates carrying curved steel screeds. Form sections were 80 ft. long.

Side-Wall Forms—The second set of forms, those for side walls, required sufficient strength for supporting the fresh concrete, equipment for lifting concrete buckets and enough chutes to meet specifications for limits of vertical and horizontal movement in the concrete. In addition, the forms had to provide clearance for trucking operations, along with ease of mobility and arrangements for rapid stripping and setting.

Wheels supporting the side-wall form ran on 90-lb. rails, re-used from the invert set-up, laid directly on continuous concrete supports poured on the invert, anchored with dowels. The structural-steel design (Fig. 23) provided an 80-ft. length of form with ribs of 16-in. I-beams spaced 9 ft. c. to c., supporting 8-in. horizontal channels, stiffened by intermediate angles and carrying the ¼-in. skin plate.

The system of chutes, seven high on each side of the form, spaced horizontally 9 ft. c. to c., met the requirements of the specifications for maximum drop and horizontal movement permitted in depositing the concrete. These steel chutes rested on 4-in. pipe rollers at the upper end to permit movement when the forms were adjusted before each pour or for moving to a new location. Provision was made for closing the chute holes as the forms filled up. Restricted headroom required a special design for the top chute in each tier. Hinged at the form end, the chute, necessarily enlarged, was lowered to a horizontal position to receive a charge of concrete and was then tilted up by means of a small air hoist to fill the highest part of the side wall.

Fig. 22—Side-wall form sections carried a crane for handling concrete buckets. Concrete was discharged through tiers of chutes on each side, properly arranged to meet specification requirements for maximum height of drop.



A toggle link near the top of the form (Fig. 23) provided for movement in releasing and centering the forms by means of pull-jacks or ratchets at the top and bottom of the form, permitting rotation as well as horizontal and vertical adjustment. After setting the form in required position with these ratchets, the jacks on each side were run out to hold the assembly in place. Hold-down bolts had been left in the edge of the invert concrete.

The electric crane operating on the top of the form was identical with the crane used on the invert gantry. Necessary ladders and working platforms were provided. Completely equipped, including crane, this 80-ft. form weighed approximately 270 tons. It was propelled along the rails by means of air-operated hoists.

Arch Form—The third set of forms and concrete-placing equipment, that for the 110-deg. arch section (Figs. 20 and 24), included an 80-ft. length of form supported on a structural-steel framework, a separate gun carriage containing two 2-cu.yd. pneumatic concrete guns with hoisting equipment, and a separate traveler connected to the gun jumbo for supporting the two placement pipes. This equipment operated on the same rails that were carrying the side form.

Because of occasional sections of overbreak, the entire arch form and supporting members were designed to carry a thickness of 5 ft. of concrete over the entire arch area. This design load produced concentrations higher than advisable for the wheels and bearings. As a result, special pedestals of cast steel were provided which spanned the rails, resting directly on the concrete shelf and, by means of jacks, removed the load from the wheels. These pedestals and jacks were fastened directly to the lower beam of the form, and during moves were raised sufficiently to clear. A set was placed under each supporting column; both the jack and the pedestal were designed for 92 tons.

Another interesting detail was the special provision for releasing the jacks between the form and the supporting structural frame in case the concrete load was too great for ordinary manual operation of the jacks. The design provided special steel wedge sections (Fig. 24) between the jack and the main horizontal supporting member, which could be withdrawn by means of bolts to release the load on the jacks. This provision was entirely a safety measure based on the realization that the weight of the concrete, combined with subsequent shrinkage and tightening of the arch might produce loads on these jacks which could not be moved by the spanner wrenches. It developed that the wedges were not necessary and the jacks could be released without their use.

The ¼-in. skin plate, supported on 8-in. channels, was maintained in position by pairs of vertical supporting jacks and inclined jacks at the edge of the arch, which held the form tight against the upper edge of the completed side wall. These wing jacks provided for bending down the lower 5 ft. of the form slightly around a point of flexure where the supporting member system was broken to permit the skin plates to bend. The two wings were lowered

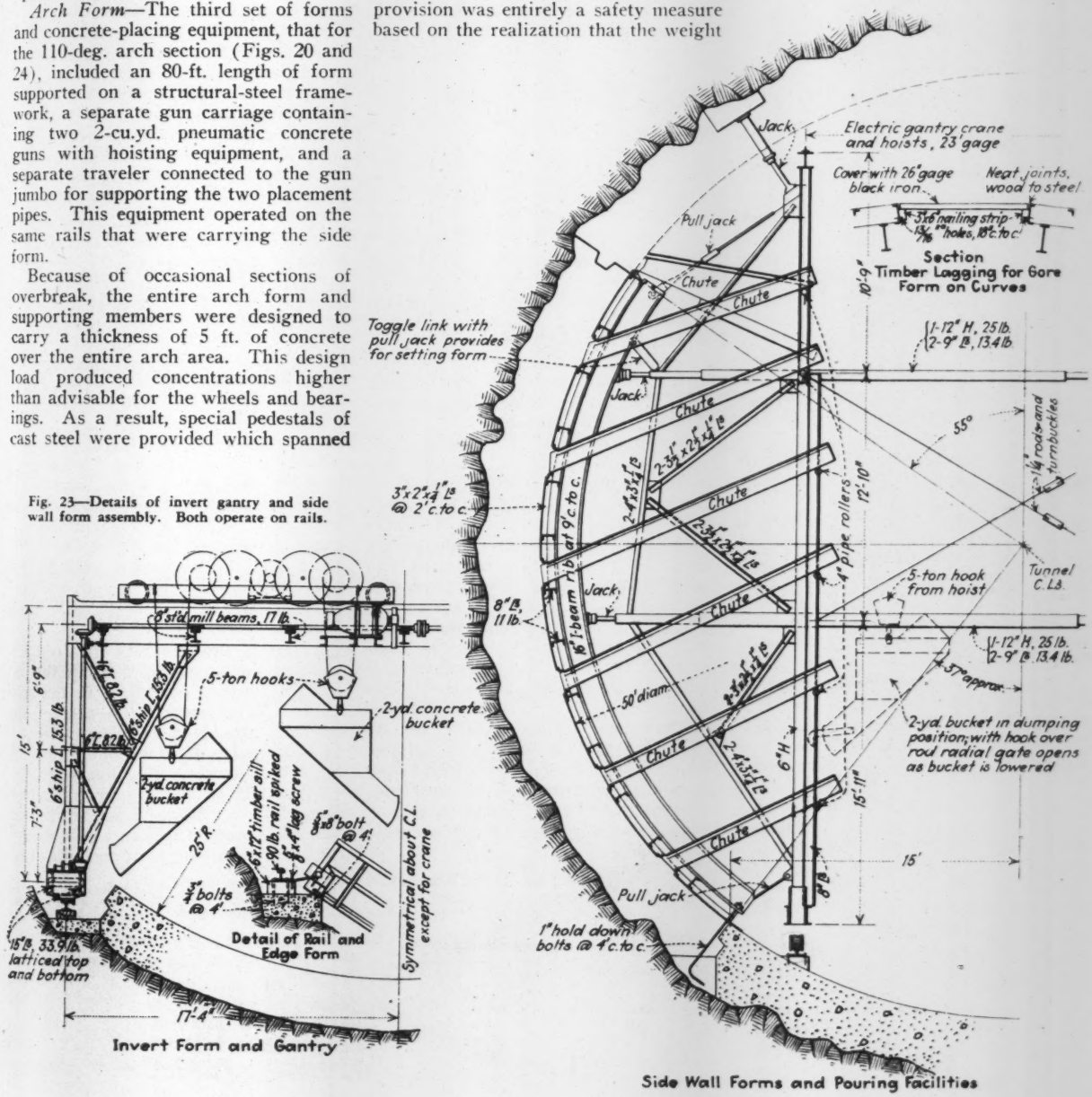

Jack
Electric gantry crane and hoists, 23' gage
Cover with 26 gage black iron
Neat joints, wood to steel
Pull jack
Chute
Section Timber Lagging for Gore Form on Curves
Toggle link with pull jack provides for setting form
1-12" H, 25 lb. 2-9" I, 13.4 lb.
55°
¼" roads and turnbuckles
3"x2"x¼" L's @ 2' c. to c.
2-4"x3½"x½" L's
2-3½"x2½"x½" L's
12'-10"
4" pipe rollers
5-ton hook from hoist
Tunnel C.L.
8" I, 11 lb.
15" I-beam rib at 9' c. to c.
50' diam.
6" H
15'-11"
15'
Pull jack
1" hold down bolts @ 4' c. to c.
Side Wall Forms and Pouring Facilities
8" std. mill beams, 17 lb.
5-ton hooks
2-yd. concrete bucket
6"x12" timber sill
50 lb. rail spiked
¾"x8" bolt @ 4'
¾" bolts @ 4'
25' R.
Detail of Rail and Edge Form
Symmetrical about C.L. except for crane
15" I, 33.9 lb. latticed top and bottom
17'-4"
Invert Form and Gantry

Fig. 23—Details of invert gantry and side wall form assembly. Both operate on rails.

slightly by this arrangement when the form was moved to a new position.

The required ladders and working platforms were provided on the arch form. It was moved ahead at the completion of the 80-ft. section by means of air-operated hoists and cables.

Gun carriage

The gun jumbo consisted of a four-wheeled frame which contained the necessary equipment for loading, operating and discharging the pneumatic concrete guns. The arrangement and design of this piece of equipment was modified from the original design, as a result of operating experience. At first the concrete guns were placed on an upper level to reduce the vertical lift of the concrete by the air. Operation of the equipment indicated that the difficulties involved in charging and operating the concrete guns at this high level were more serious than the problem of raising the concrete by air, and as a result the arrangement was changed to place the guns near the invert, making the air lift approximately 45 ft.

In addition to the two guns, this jumbo carried two large air receivers and hoisting equipment to lift the 4-cu.yd. agitator bodies off the trucks and discharge their contents half into each gun. From the guns the 6-in. steel discharge pipes turned upward on a 10-ft. radius and were supported at the upper level on a separate light steel traveler which was connected to the gun jumbo by timbers. At the lower pipe elbow was an extra piece of blanked straight pipe that provided a concrete wearing surface at the first curve. A length of 6-in. hose was used for the upper bend in the discharge line.

* * *

II—*Tunnel Concreting Procedure*

TO PROTECT tunnel-lining operations during the summer months of floodflow in 1932, temporary cofferdams were required at the portals of the tunnels. Driving operations (*ENR*, June 16, 1932, p. 853) were rushed during the low-flow winter months (1931-1932), and uninterrupted work on the tunnel lining was necessary for continuity of progress on the general project. During low flow, foundation sections for concrete-arch cofferdams were built around the tunnel portals. Later in the spring the side sections of these arches were carried to full height, leaving a center slot for more convenient trucking operations. Finally the arches were continued to their full height of 40 ft., and vertical steel H-beams were embedded in the crest to provide for an additional 5 ft. of wooden flashboards if required.

These arch cofferdams were of typical thin-arch design with a crest thickness of 18 in. and a bottom thickness of 3 ft. 2 in. on the center of the span. The abutments of the arch were thickened to 2 ft. 6 in. at the crest and 6 ft. 2 in. at the base. Abutments were doweled into the canyon rock, and reinforcing was provided on both faces—1-in. round bars at 24-in. centers horizontally and ¾-in. round bars at 6-in. centers vertically. The structures were founded on solid rock and in every respect represented well-designed and constructed arch dams. The timber forms were left in place, and pipes were embedded in the concrete to facilitate blasting operations for removal.

The maximum flood of the 1932 season occurred on May 27, when a discharge of 103,500 sec.-ft. was measured at the canyon—a flood of fair volume, though far below the greatest that might be expected. The river during this flood reached a stage of El. 670, 30 ft. above the tunnel invert and 5 ft. below the crest of the arches.

After the arches had been raised to their total height, trucking operations were carried on over fills of tunnel spoil on the outside of the dams and down long timber ramps (Fig. 20) to grade on the inside.

Transportation—All concrete for the tunnel lining was mixed at the low-level mixing plant located on the Nevada side of the river about 2,000 ft. upstream from the tunnel portals. Truck transportation was used exclusively, consisting of either two 2-cu.yd. form buckets carried on platform trucks or 4-cu.yd. agitator bodies. The former method was used at the start of the work when the haul was comparatively short, but trouble was experienced with packing and clogging on discharge, and the mixer bodies that could agitate the concrete just before placing were found more satisfactory. Mixing was completed at the plant, and the contents of each 4-yd. mixer discharged directly into the agitator body. The material was not revolved during transit, but on arrival at the forms it was agitated during discharging to overcome any possible segregation and improve consistency. Agitator drums were revolved also when any tie-up occurred in transportation.

In general, all lining operations started from the upstream portals and progressed downstream, with the trucking distance increasing as the work progressed. This required the moving of trucks for the lower operations through the side-wall and arch forms. During maximum operations as many as eighteen of the agitator-body trucks were in use.

Invert—Preparations for invert lining and the gantry crane that handled the invert concrete have been described. On arrival at the place of pour, agitator trucks emptied into the 2-yd. buckets, which were picked up (Fig. 21) and spotted by the gantry crane. As soon as sufficient concrete had been deposited along the bottom under the screeds, two steel strike-off plates supported on a light steel bridge and curved to tunnel radius were pulled outward from the center by hand winches at the edge of the invert. This operation established the curvature of the invert, and then the surface was finished, first by wooden floats and lastly by steel trowels. Finishing was carried on from light steel bridges, and the equipment was moved ahead by hand or by the gantry.

Bulkheads for construction joints in the invert were provided every 40 ft. in the upstream section of the tunnels, where they will be used for diversion purposes only, but this spacing was reduced to 26 ft. 8 in. down-stream from the locations of the plugs in the spillway tunnels (Nos. 1 and 4). This same spacing of construction joints also applied to the side walls and arch sections.

Following placing of the invert concrete, the new concrete rail shelves were poured on the invert and the rails moved over from the original supports to carry the side-wall and arch-form equipment. These shelves on the invert will be left in place in the upstream sections of the tunnel above the plugs, but the contractor will be required to remove them downstream from the plugs where the tunnels will be in permanent use.

A special problem was involved because of the necessity of using the invert for trucking operations in the subsequent lining work. To protect the concrete, provide a sufficient width of roadway and protect the outer tires on dual-wheel trucks, the invert section was backfilled with fine rock spoil, end-dumped from trucks as the work progressed to provide a 25-ft. width of level roadway extending between the rails

RECORD OF TUNNEL LINING PROGRESS BY MONTHS

	Progress Footage in Four Tunnels			Yardage of Concrete Placed in Four Tunnels	
1932	Invert	Sides	Arch	Net (Cu.Yd.)	Gross (Cu.Yd.)
March	300	.....	.....	1,100	2,210
April	2,300	.....	.....	9,100	12,210
May	1,000	1,700	.....	19,400	27,380
June	3,100	1,850	700	32,400	43,800
July	3,800	3,050	1,900	52,600	65,580
August	2,200	3,000	2,700	50,700	62,650
September	400	1,600	3,100	33,400	40,570
October	850	1,400	1,840	26,700	38,680
Completed October 31	13,950	12,600	10,240	225,400	293,080
	88%	79%	64%		

that supported the side-wall forms. This backfill amounted to about 2½ cu. yd. per lineal foot of tunnel. In addition to providing a roadway, it protected and helped to cure the invert concrete. Upon completion of all lining work this backfill was removed by a shovel operating on pads, loading into trucks. The shovel dipper was equipped with a blade instead of teeth, and with the aid of several clean-up men the tunnel was cleaned without difficulty to the point of final flushing.

Side Walls—With the inside rails and the road completed, the tunnel was ready for placing the concrete in the side walls (Fig. 22). In the concreting operations, proper rotation was maintained to fill up the side walls for each 40-ft. or 26 ft. 8-in. section evenly on both sides. Men worked behind the form to puddle the concrete against the rock, and as the concrete rose the chutes were withdrawn and the openings in the form covered with steel plates.

Temporary timber bulkheads were placed to provide construction joints between pours with a simple offset keyway 1½ in. deep and 10 in. wide. A 40-ft. section contains 360 cu.yd. of concrete (net) and required from ten to fifteen hours to place, depending upon the amount of overbreak. A period of six hours was allowed before work started on the next section. With completion of the two 40-ft. pours or the three pours of shorter section, the form was left in position twelve hours and then moved ahead to the next position. The same general procedure was used where the three 26-ft. 8-in. sections were placed. The crew required to operate this equipment pour was about 20 men.

Arch—The arch-placing equipment was next moved into position (Fig. 20), keeping not less than 150 ft. behind the completed side walls. Each truck moved in under the hoist on the gun jumbo, and the agitator body was lifted off the truck. By means of a swivel attachment and equalizing spreader the contents were divided between the two 2-yd. concrete guns. Meanwhile the truck moved ahead, turned around on the invert roadway, widened by planks on the lower side wall and returned to pick up the empty agitator.

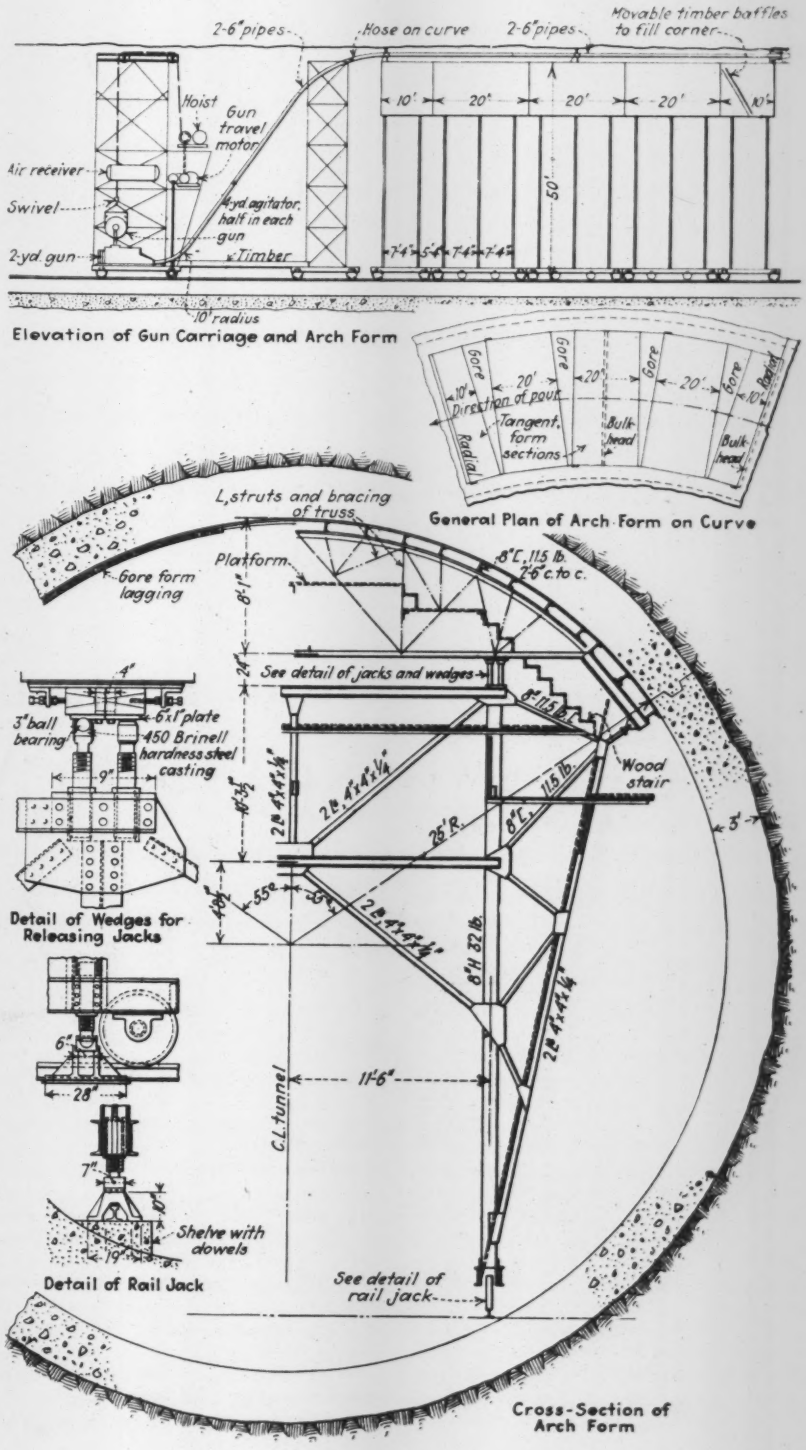
Operation of the pneumatic concrete guns followed standard procedure, using the compressed-air supply already available in the tunnel. A large air receiver was used with each gun, and the nominal pressure was about 100 lb., but it often dropped almost 50 per cent near the finish of a 2-yd. charge of concrete.

At the completion of each arch section two pockets 3 ft. deep were left at the bulkhead near the crown. Into these pockets were placed the ends of the two 6-in. discharge pipes at the beginning of the next arch pour. This procedure was to keep the ends of the pipe lines always in fresh concrete. Also light timber baffles were set up on the form near the front end of the pour to deflect the concrete into the lower corners of the arch. During concrete placing the gun jumbo was withdrawn under its own power, keeping the ends of the discharge pipes in the concrete.

Fig. 24—Arch-form assembly and details of design. Insert shows how tangent form sections were fitted with gores for curved portions of tunnels.

Spacing of construction joints in the arch corresponded to that in the side walls and invert. A period of twelve hours was allowed to elapse between the completion of the last pour and the removal of the arch form.

Progress Rate—Tunnel lining began on a small scale with the placing of 500 lin.ft. of invert in March and accelerated rapidly to the month of July, after which



the rate declined as various operations have been concluded in the different tunnels. The maximum day's output, on July 17, placed 2,750 cu.yd. of gross lining, and throughout the month of July the output averaged nearly 2,300 cu.yd. gross per day. The accompanying table, compiled from the contractor's records, shows the monthly progress on the three operations together with the figures indicating the concrete placed both net and gross. The net yardage per foot of tunnel for the three sections of lining is 3.8 cu.yd. in the invert, 9.0 cu.yd. in the walls and 5.7 cu.yd. in the arch, totaling 18.5 cu.yd. for the complete circular lining.

From the beginning of lining operations in March to the month of September, concrete placing averaged 895 cu.yd. net and 1,178 cu.yd. gross per day. This indicates that the overbreak amounted to about 6 per cent of the 56-ft. diameter to the outside of the tunnel lining and 30 per cent over the actual average lining area required by specifications.

Special Problems—The side-wall and arch forms, as constructed, operated on the tangent sections of tunnel, but provision was made for fitting them to the various curved sections. As constructed the forms were composed of three 20-ft. main panels with 10-ft. end sections and could be unbolted for the insertion of timber gores on the curves. As it was considered undesirable to have sharp angles on the inside of the curves, minimum gores of 1 ft. were placed on the inside with the gore width increasing to the opposite side, amounting to as much as an 8-ft. opening on the sharpest curve. Thus, the curves present a surface consisting of 20-ft. tangents broken by the shorter gore sections. As only a few of the tunnel curves were of the same radius the gores were built of timber and used only once or twice.

Tunnel design calls for wedge-shaped tunnel plugs on all four tunnels upstream from the point where each will operate as a permanent feature either as spillway or penstock. Special wedge-shaped timber pads were provided for these plugged sections, bolted to the outside of the tunnel-lining form. The result was to make the 3-ft. lining continuous over the plug section to prevent any possible damage during the diversion operations and reduce friction loss. The timber pads were left in place to present a smooth face in the tunnel during diversion. Later they will be removed and the plug sections poured.

A serious operating problem was provided in keeping the transportation going smoothly when more than one of the lining operations was in progress in the same tunnel. There were occasions when all three operations were going simultaneously in the same bore, providing a concentration of trucking. The invert roadway, as described, provided an ample two-lane truck road, but there were bottlenecks where the trucks with invert concrete had to get through the arch and side-wall forms. Different mixes used for the three sections of lining made it impossible to divert the trucks as needed and required three distinct truck fleets for such operation.

Curing also provided difficulties. The invert section was easily taken care of by the road material that kept the concrete moist without trouble. A two weeks' spray cure was called for in the specifications. When this was started on the side walls it was found that the water running from the side walls collected in the roadway fill, softening the road. Also during the summer months the temperature in the tunnels was extremely high, and the humidity resulting from spraying made the working conditions severe. As a result the curing process was changed to an asphalt-oil coating (Fig. 20).

Lining Concrete—Concrete for the tunnel lining was batched and mixed at the low-level plant (*ENR*, April 4, 1932, p. 534). The aggregate was prepared and graded in the screening plant (*ENR*, June 2, 1932, p. 783). Volume of concrete mixed per shift for the lining operation did not reach the capacity of the four 4-yd. mixers, but all of the equipment was in use at various times because three different classes of concrete were required.

Concrete for the invert and side walls used aggregate sizes up to a maximum of 3 in., and the arch concrete had a 1½-in. maximum size. Lining concrete averaged about 1-1/3 bbl. of cement per cubic yard; cement is furnished by the government. The mix for the invert and side-wall concrete was approximately 1:2.2:4.6. The slump of the concrete in the various sections, as placed, was: invert, 3½ in.; side walls, 4½ in.; arch, 5 in.

Grouting operations, which are extensive, involving both low-pressure filling of the concrete (rock contact in the arch section) and a high-pressure system of deep holes, will be covered in subsequent treatment. High-pressure grouting will be delayed until the diversion tunnels are unwatered.

Personnel—In addition to the general personnel of the Bureau of Reclamation and Six Companies Inc., listed elsewhere in this issue, O. G. Patch was supervisor of concrete production for the government, and Bernard Williams, assistant general superintendent, was in charge of concrete operation for the contractor.

* * *

While major construction activities in the canyon to date have centered on the tunnel-driving and lining and diversion of the river, other important features of the work have been under way and will continue to hold interest for the next few months. Spillway and intake construction and canyon-wall scaling, all spectacular operations, are described next.

Other Features of Project Well Under Way

Spillways excavated and ready for lining operations—Spectacular wall scaling and intake-tower cuts in canyon walls well advanced—Extensive system of cableways to cover entire site started

CONCENTRATED activity on the lining of the diversion tunnels during the past six months has not interfered with large-scale operations on other features of the Hoover Dam construction program, which will carry forward and expand in the coming seasons. More than 550,000 cu.yd. of solid rock has been taken out of the two spillway cuts; the 600-ft. inclined tunnel from the Nevada spillway has been driven and enlarged; and the hazardous work of cutting out the foundations for the four intake towers is nearly completed, and canyon-wall scaling is well advanced. Preliminary work on preparing and erecting an extensive system of 20-ton traveling cableways to cover the entire site has advanced to the stage of erection. Operations at the aggregate plant have been carried on in excess of lining demands, and 500,000 cu.yd. of prepared material is in stockpiles. These operations indicate the well-rounded progress on the work and the assurance that with diversion accomplished there will be no interruption or delay in carrying forward the second stage of the project—the foundation preparations prior to full-scale concreting. The construction operations other than tunnel lining and the diversion program and their relation to future work are outlined in the following.

Spillway system

Modified from the design presented in the original plans, the two spillways

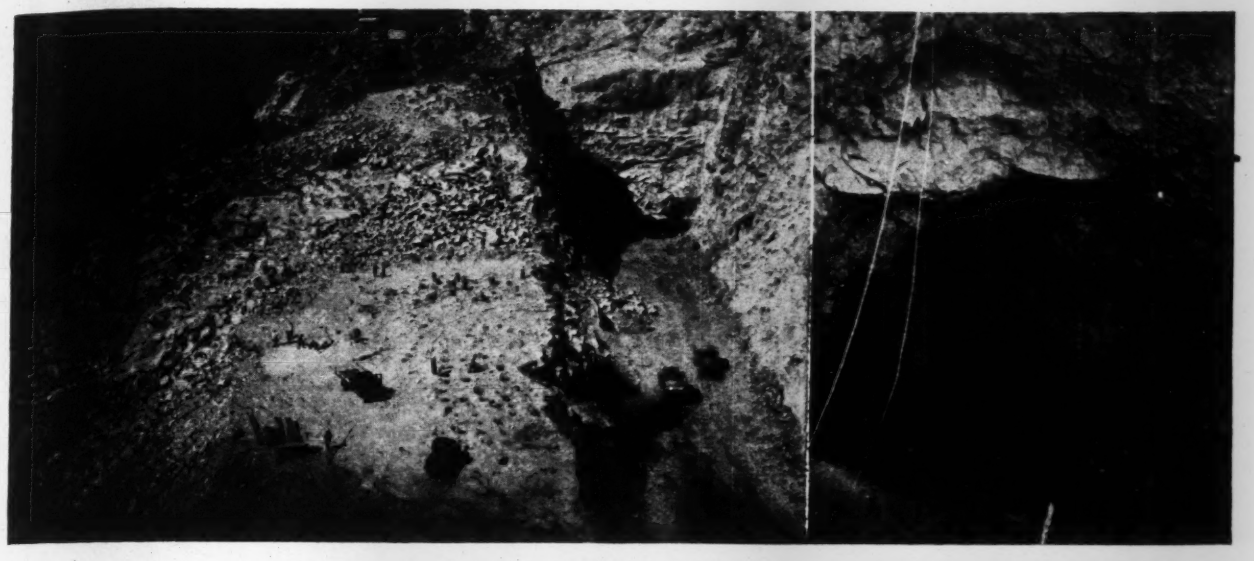


Fig. 25—Mammouth spillways are required to carry floods of 400,000 sec.-ft. Left: 300,000 cu.yd. of solid rock has been taken out of Nevada spillway cut. Size of cut is indicated by 4-yd. shovel at far end. Drill crew is working on overflow structure foundations. Right: Enlarging Arizona inclined spillway tunnel by glory-hole method.

one on each side of the canyon, involve about 625,000 cu.yd. of solid-rock excavation, which has been taken out by open-cut methods. The original spillway design contemplated an excavation exceeding 1,000,000 cu.yd. in these cuts. The two spillways are of side-channel type 650 ft. long and will be fitted with four 100x16-ft. drum gates. Discharge will be through 50-ft. inclined tunnels 600 ft. long connecting with the outer diversion tunnels Nos. 1 and 4. In the concluding stages of the work these diversion tunnels will be plugged upstream from the junction with the inclined tunnels. Spillway cuts will be lined with 24 in. of reinforced concrete; the tunnels will have concrete lining of 36 in. average thickness. Construction of the overflow sections of the spillways will require 100,000 cu.yd. of concrete and, in reality, involve the building of two low concrete dams several hundred feet long.

Work has been confined to excavation, and this has been practically completed for both. The Nevada spillway was started earlier because of its accessibility; the Arizona spillway was not available until a 3-mile construction road from the lower portals of the Arizona diversion tunnels had been completed in heavy rock work, with grades reaching a maximum of 30 per cent. After completion of this road the work in the Arizona spillway was rushed.

The most serious difficulty in the excavation of the spillways is the disposal of muck. Drilling has been confined principally to down-holes put in with jackhammers. Blasted rock is loaded onto trucks by the same electric shovels that handled the tunnel muck. Available areas for disposal of excavated material are scarce, and can be reached only by travel over steep roads containing many hairpin turns.

The spillway floors slope at a 10 per cent grade toward the discharge shaft, and a weir is provided to still the water before it enters the inclined shaft. This weir is formed by a 26-ft. vertical step near the lower end of the spillway channel, and only the overflow will discharge into the shaft. A small tunnel will drain the reservoir that is formed behind the weir.

Each of the inclined tunnels was raised with a pioneer top-center heading 7 ft. high and 14 ft. wide. On the Arizona side this pioneer heading has been holed through, but enlarging operations will be delayed for another year while the lower tunnel is being used as the principal diversion channel. On the Nevada side the work started earlier and the tunnel enlargement has been completed. From the pioneer raise the heading was deepened by jackhammer bench-drilling in successive cuts to the 56-ft. diameter of the tunnel (Fig. 25). The remaining operation consisted of enlarging the wing sections by glory-hole methods, working from the top and allowing the rock to move by gravity to the diversion-tunnel level where it was loaded by shovel into trucks for removal. Men and equipment were handled by hoists operating from the spillway end.

Canyon wall scaling

The most spectacular work is the scaling of the canyon walls, required on both sides of the river above the outlet-valve houses, penstock-tunnel adits, power-house structure and the actual dam site, where the work will continue in the form of abutment excavation. Very similar to this work has been the excavation for the four intake towers

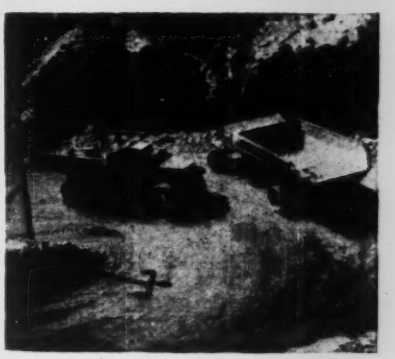


Fig. 26—Hairpin turns and steep grades abound on road built solely for disposal of spillway muck.

where deep cuts in rock were required to bench out for foundation areas. About 40,000 cu.yd. of rock has been stripped from the canyon walls, and the total yardage of scaling will depend on the character of rock as the work progresses. The original estimate in the specifications for canyon-wall scaling was 150,000 cu.yd. Removal of rock for the dam abutments is merely a continuation of this operation, and already some rock has been removed that has been classified under the 400,000 cu.yd. estimated for the total dam excavation. The scaling crew numbers about 150. Because of the hazardous nature of this type of work and the difficulty of providing illumination, operations as yet are carried out only on the day shift.

Much thought was given to the carrying out of this work, and many ideas have been advanced as to the best method. Considering all the difficulties involved and the practical means available, the contractor finds that the use of rope slings in which men are lowered down from the top of the cliffs as the work advances is the most satisfactory. In this procedure the first operation is to bar down all loose rock encountered,

with the men working in slings above the rock to be pried loose. Men in these crews are all required to wear hard hats and are provided with safety belts and short ropes with which to attach themselves to the permanent lines when working out of the slings. Following the barring down of all loose rock on a particular section of canyon wall, jackhammer operations follow and the section is shot, after which the loose rock is again barred down.

The sight of dozens of men dangling from ropes or working like flies on the slopes of rock 600 ft. above the river (Fig. 27) is of unceasing interest to the usual run of visitors on the project. In addition, the blasts from these operations and the resulting clouds of rock dust in the canyon (Fig. 28) present one of the more spectacular phases of the work.

Intake-tower excavation

Intake-tower excavation procedure has involved methods very much the same as those used in scaling. The work started six months ago, and now about two-thirds of the estimated 320,000 cu.yd. has been removed. The original slope of the canyon at the tower locations was about ½:1, and the cuts are sloped ¼:1. Fig. 29 shows roughly the maximum section through one of these cuts and the method of jackhammer drilling for rock excavation. In early stages these cuts were steep enough to provide gravity disposal of the rock into the canyon. As the cuts deepened and the slope decreased, some hand-mucking was required, and finally a tractor with bulldozer was used to push the rock over the edge into the river channel where it is removed by shovel and trucks.

Excavation of abutments for the actual dam will be similar to the scaling and intake-tower operations. Because of the narrowness of the canyon it will be impossible to work in the foundation area until the wall scaling and abutment excavation have been completed. With the river diverted the scaling crews in the dam site have been increased, and the work will be carried down along the finished abutment lines as the work progresses. The abutment excavation should be completed down to the bottom of the canyon by early spring. Foundation excavation will follow immediately, and according to the present schedule concreting operations should be under way by July, 1933.

Cableway system

A system of five 20-ton cableways, now under construction by the contractor, is designed to cover all parts of the work from the spillways to the lower end of the power plant. In addition to the 20-ton units, the 12- and 35-ton units in present operation at the up- and downstream portals of the diversion tunnels will remain in use. Also the light cableway will continue to transport scaling crews to the Arizona side, thereby eliminating a 6-mile ride.

The five units of the cableway system have been standardized on a 20-ton size to provide for economy in equipment and maintenance. Operation and control end of all cableways will be on the Nevada side. The general features of the cableway units, beginning at the upstream end, are as follows.

Two parallel traveling cableways of 2,575-ft. span with runways 700 ft. long will cover the spillway structures, the four outlet towers and the section of the dam upstream from the crest. The runways for these cableways will be at El. 1,350, and head and tail towers will be 90 ft. high. The length of span is necessary to reach the spillway structures several hundred feet back from the canyon rim.

Adjoining downstream and covering the next section of the work will be two 20-ton cableways of 1,385-ft. span. This double unit will be slightly radial with head-tower travel of 500 ft. and tail-tower travel of 380 ft. The runways will be at El. 1,340, and a 75-ft. head tower will be provided for each cableway. The tail towers for the two will be 42 ft. high. The site for this pair of cableways provided serious problems for foundations and necessitated a structural-steel trestle for the head tower on the Nevada end and a rockfill on the Arizona side. This pair of cableways

Fig. 27—Scaling crews 600 ft. above the river prepare sites for the intake towers and strip the dam site prior to abutment excavation. The crew is at work on the type of cut shown in Fig. 29. Bridge at upper right was used in dumping rock for temporary diversion dam. Roadway on fill from the bridge to lower right corner is the Nevada side of the permanent upstream cofferdam site.

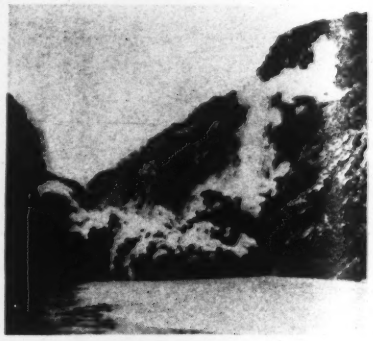


Fig. 28—Rolling down into the canyon come the rock and dust clouds from stripping blasts on the walls.

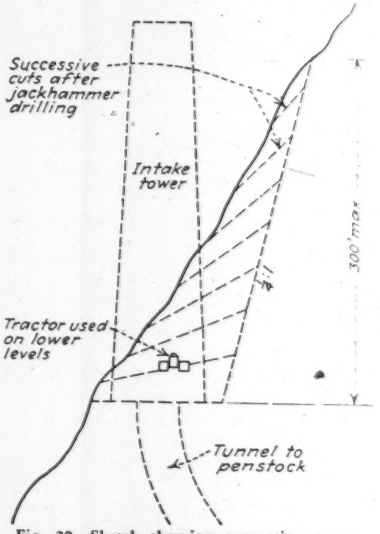


Fig. 29—Sketch showing excavating procedure on a section through one of the deep cuts for the intake towers. Successive blasts after jackhammer drilling brought the canyon wall down a ¼:1 slope. Gravity, hand-mucking and finally a tractor disposed of the rock.

covers the dam proper from the crest to the downstream toe and also reaches the upper end of the power house structure.

Connecting downstream from this second pair of cableways will be a 20-ton radial unit of 1,365-ft. span. A 98-ft. stationary head tower will be located on the Nevada side of the canyon at El. 1,280, and a 16-ft. traveling tail tower on the Arizona side will be at El. 1,225. This radial unit completes the coverage of the entire canyon area down to the location of the 150-ton cableway under construction by the government to handle the penstock pipe sections and other heavy equipment.

The contractor's cableway system will be in operation and will be used extensively for handling of excavated material, concrete and equipment throughout the remainder of the work. For transporting concrete the cableways will operate with 8-cu.yd. concrete buckets; 12-yd. skips will be used to handle a large part of the excavated material out of the dam site for transfer into trains.

To complete all excavation work in the high levels of the canyon prior to the beginning of work at lower elevations, preparations are being made for the future construction of the high-level concrete mixing plant. All rock excavation work has been completed for this unit, which will contain two 4-yd. mixers in its first layout with the possibility of doubling its capacity when the low-level plant has to be discontinued. Access to the high-level plant is provided by extension of the government railroad past the main substation to the edge of the canyon to permit dumping aggregate direct into storage bins and unloading cement by downhill piping. Below this storage, batchers will be installed from which conveyor belts will carry the aggregates to mixer hoppers. Details of this plant are being worked out now, and it is expected to have it operating with two mixers about March, 1933.

* * *

Now that the first stage of construction operations is finished, what is next? In the following article the future program and revised schedule, made necessary by early completion of the tunnels, are presented.

Rapid Progress Revises Construction Schedule

Diversion of river a year early advances completion dates of all remaining work—Power to be generated by September, 1935—Future program outlined

PHENOMENAL progress in driving and lining of the four 50-ft. diversion tunnels at Hoover Dam resulted in the turning of the river into the two Arizona tunnels on Nov. 13, almost a year ahead of the diversion date contemplated at the time of award of contract. Consequently, completion dates of various parts of the work yet to be done have been advanced. An outline of the future construction program is presented in the following, prepared by the Denver office of the Bureau of Reclamation.

The two tunnels on the Nevada side will be completed prior to the beginning of next spring's flood runoff, and the entire period of diversion will probably be advanced a full year, permitting water to be stored in the reservoir to an elevation sufficient to allow discharge through the outlet-works towers by Sept. 1, 1935. Generation of power will also commence by this date, one year in advance of the date originally planned.

In order to accomplish this result, however, the same rapid pace set in the construction of the tunnels must be maintained in the construction of other major features, such as the permanent cofferdams, excavating for and placing the mass concrete in the dam, the outlet works and intake towers, the involved tunnel penstock system, the plate-steel pipe, gates, valves and other machinery, the tunnel plugs in the diversion tunnels, and the building of the power plant itself with the installation of the first units required for power development.

The contractor and the government are cooperating to the end that all interlocking features of work may be commenced and completed at the proper dates to insure the initial generation of power at the earliest possible date. Fig. 30 is a pictorial construction-progress diagram, showing tentative dates for commencing and completing different features of the work. A similar cart, of the original schedule, was published in *ENR*, Dec. 25, 1930, p. 1,012.

Construction of the upstream cofferdam is already well under way. This was commenced prior to diversion of the river by building a semicircular cofferdam out into the Colorado River from the Nevada cliff, thus unwatering half of the site. The cofferdam, together with downstream cofferdam and rock barrier, should be completed by early spring, prior to the heavy runoff.

Heavy concrete schedule

The program calls for completion of all excavation for the dam by July 1 of next year. Probably the most ambitious part of the program is the placing of 3,500,000 cu.yd. of concrete in the

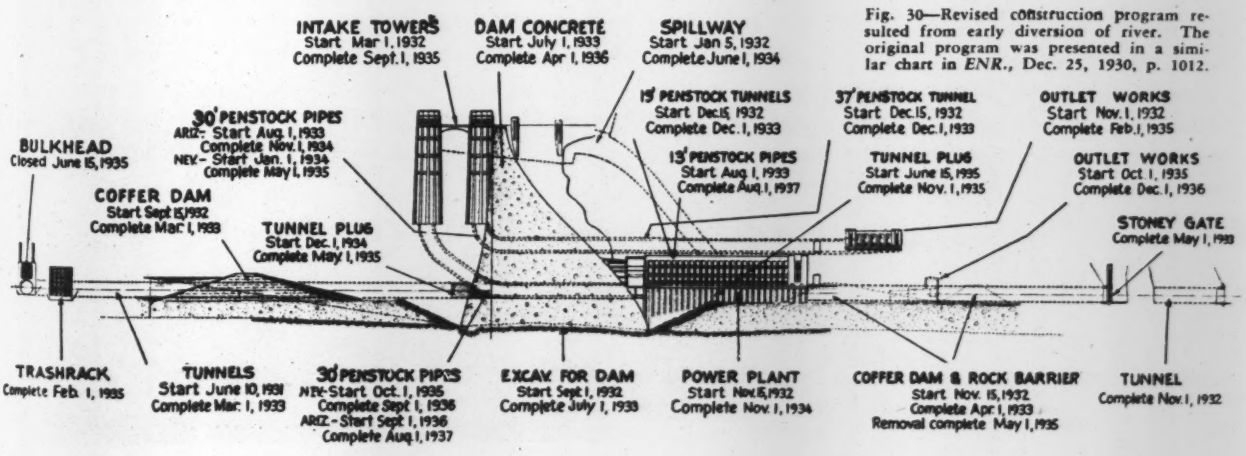


Fig. 30—Revised construction program resulted from early diversion of river. The original program was presented in a similar chart in *ENR.*, Dec. 25, 1930, p. 1012.

period from July 1, 1933, to April 1, 1936. This represents an average concrete placement of more than 100,000 cu.yd. per month. However, to maintain this program in the face of certain necessary requirements and interruptions, it will be necessary to place about 150,000 cu.yd. per month for several months. It is estimated that the peak placement will amount to nearly 175,000 cu.yd. per month.

Placing of the mass concrete is limited somewhat by certain design features. Vertical radial and circumferential contraction joints are provided for the expansion and contraction of the concrete in horizontal directions. These joints will divide the dam into blocks or columns. Grouting of the joints after dissipation of the setting heat in the concrete will result in a monolithic structure.

The specification requirements for the mass concrete provide that placing must commence in the panel in the lowest part of the foundation. The concrete must be placed in horizontal layers not exceeding 5 ft. in thickness. In placing the concrete the top of any two blocks must at no time differ by more than 35 ft. in elevation. The rate of placing concrete in any column must be such that not more than 5 ft. in depth shall be placed in 72 hours, and not more than 35 ft. will be placed in a 30-day period. These restrictions will govern to a large extent the time required to place the 3½ million cu.yd. of mass concrete in the dam.

Cooling system

The requirement for cooling the mass concrete in the dam after it has been placed is a new feature dictated by the massive dimensions of this dam, making it advisable in order to secure the best possible quality of concrete to remove chemical heat, which otherwise might remain in the dam for many years, with resultant cracking as it cools. The excess heat is removed by embedding a system of 2½- or 3-in. pipes in the mass concrete as it is placed. After the concrete around these pipes has set for a minimum period of six days, water of a considerably lower temperature than that of the concrete but not lower than 35 deg. F. will be circulated through the pipes. The contract for the construction of the dam calls for the furnishing, installing and operating of a complete refrigeration plant for this purpose. The contractor is now making preparations to install this plant.

The pipe embedded in the concrete for cooling purposes will amount to about 800,000 lin.ft., and nearly 16,000 expansion-type couplings will be used for connections across the contraction joints. Horizontal spacing of the pipe will be 11½ ft. c. to c., with the pipe in alternate horizontal tiers staggered and the tiers placed vertically 10 ft. c. to c. The cooling-pipe syytem will be a series of loops, each with a total length of about 1,600 ft.

Selection of the proper date for closing the bulkhead gates is one of the most important features of the construction program for Hoover Dam. This has been tentatively set for June 15, 1935, which is shortly after the peak discharge for the average year, as indicated by numerous runoff records of the Colorado River. However, the date finally decided upon will depend upon snow surveys and water-supply studies made during the spring of 1935. It will be the aim in selecting the date of final closure to insure that sufficient water is stored from the flood runoff to attain and maintain the desired minimum water surface at El. 935, and at the same time to insure that the amount of storage is not greater than can be controlled by the units of the outlet works completed at that time.

* * *

Design of the world's highest dam did not end with the preparation of the contract drawings. Continued investigation and study have been under way by the Bureau of Reclamation. The results of this extensive research program have been the removal of many points of former doubt and the saving of over $2,000,000 in construction costs. This research program is briefly outlined in the next and last article.

Construction Guided by Extensive Research

Studies of cement, action of dam, hydraulics of side-channel spillways, tunnel erosion, intake tower gates, penstock losses and steel outlet conduits result in large savings at small cost

By Elwood Mead
Commissioner, U. S. Bureau of Reclamation

INTELLIGENT research has supplied the civilized world with practically all of its important achievements. The successful development of any engineering work of unprecedented magnitude necessarily involves a vast amount of research. Hoover Dam is no exception. The program of investigation and tests carried on in connection with this great project has already resulted in savings of construction costs amounting to $2,170,000, many times the cost of the research work.

Hoover Dam, when completed, will rise 732 ft. above the bottom of the canyon, a height nearly twice as great as that of Owyhee Dam, which is today the world's highest dam. Hoover Dam will be provided with spillways and outlet works for a maximum floodflow of 500,000 sec.-ft. It will raise the water surface in the canyon 582 ft. above mean low-water elevation of the river and impound enough water to cover the state of Connecticut 10 ft. deep. It will require the controlled release of large quantities of water under heads that may sometimes be more than 300 ft. All these are conditions of unprecedented magnitude. It is but natural, therefore, that the design of Hoover Dam should require an extensive program of research activities.

The research investigations that must be made in connection with the design of Hoover Dam include delving into the

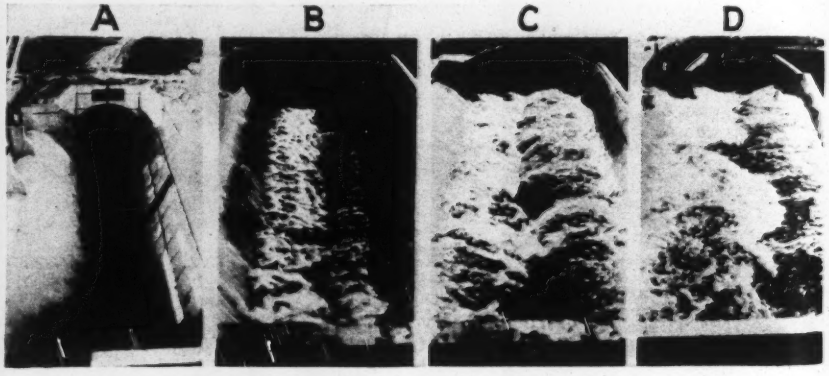


Fig. 31—Spillway discharge tests on model of 1:20 scale at Montrose, Colo., laboratory. In view A, no discharge. In B the discharge corresponds to $Q = 31{,}000$ sec.-ft.; in C to 120,000 sec.-ft.; and in D to 200,000 sec.-ft., which is maximum floodflow for one spillway.

Fig. 32—Plaster of paris and celite model of dam ready for testing.

realms of mathematics, mechanics, elasticity, physics, hydraulics, chemistry, seismology, structural geology and other branches of science. They include the development of new mathematical equations, new methods of stress analyses, new methods of model testing, new specifications for cement, new determinations of the thermal properties of concrete, and new features of hydraulic, mechanical and structural design, as well as extensive studies of all the engineering developments that have heretofore been made in the design and construction of masonry dams and appurtenant works.

Some of the research activities have already been described in the pages of *Engineering News-Record*. Others will be described in future issues, in detailed articles prepared by different engineers connected with the resarch work. This article will present only a brief picture of the research investigations, a picture necessarily incomplete since many of the problems have not yet reached a stage of completion that would warrant the publication of definite data and results.

Technical design

The technical design of the dam required the solution of many problems of a research nature. It was necessary to prove that arch action will take place in a massive arch-gravity dam of the type selected, and to establish the accuracy of the trial-load method of analyzing the action of a massive masonry dam. It was necessary to determine accurately the effects of tangential shear, twist, Poisson's ratio, flow, internal temperature variations, radial cantilever sides, foundation and abutment deformations, earthquake shocks, spreading of canyon walls due to reservoir water pressure, uplift pressure at the base, uplift pressure within the pores of the concrete, etc. The magnitude and distribution of stress in all parts of the foundations and abutments, as well as in all parts of the dam itself, had to be determined under all possible conditions of loading. Effects of non-linear stress distribution in all parts of the structure, in both arch and cantilever elements, had to be evaluated. It was necessary to investigate the stress conditions that will be caused by subcooling, by the grouting of the construction joints and by other load conditions that will be encountered during the placing of so large a quantity of mass concrete in so short a time.

The technical studies have necessarily been largely a matter of higher mathematics, based on the theories of mechanics, particularly the theory of elasticity. However, they have also included researches of all that has heretofore been accomplished in the field of stress analyses. They have also included a comprehensive program of arch-dam model testing carried on at the University of Colorado in cooperation with the Engineering Foundation arch dam committee. This program included the building and testing of a concrete model of the Stevenson Creek test dam, the building and testing of a concrete model of Gibson Dam, an elaborate investigation of materials suitable for building and testing models of massive structures, and the construction and testing of a plaster of paris and celite model of Hoover Dam. The construction of a soft rubber model, for the purpose of checking the results obtained on the plaster and celite model, is now under way.

Some of the results of the arch-dam model program obtained thus far have already been published (*Civil Engineering*, May, 1931, p. 695, and *ENR*, April 7, 1932, p. 494). It was found that the radial deflections measured on the arch-dam models agreed very satisfactorily with those calculated by the trial-load method. The tests of the model of Hoover Dam showed conclusively that arch action will take place in a massive arch-gravity type of dam, that only a few minor modifications in horizontal curvature are desirable in the final designs, and that the type of dam adopted is logical, adequate, and entirely safe for all conditions of load.

Cement and concrete

Two of the most important and difficult concrete problems in connection with the design and construction of Hoover Dam are the heat generation in a large mass of concrete due to the hydration of the cement as the mixture hardens, and the volumetric changes occurring in mass concrete due to temperature variations and other causes. These problems have received but scant attention in previous investigations of concrete manufacture. They have necessitated the inclusion of two special provisions in the design of the dam: circumferential contraction joints, and an elaborate artificial cooling system that will lower the temperature of the concrete to normal, or subnormal, values before grouting the construction joints. They have also necessitated the institution of an elaborate cement and concrete research program in order to determine the best types of cement for use in the construction of the dam, the values of the thermal constants involved in the refrigeration calculations, the maximum temperature rise that will occur in the interior of the dam during the setting of the concrete, the practicability and efficiency of the refrigeration system as a whole, and other miscellaneous problems of a thermal nature connected with the construction of the dam and the temperature loads to which it will be subjected after the reservoir is filled as well

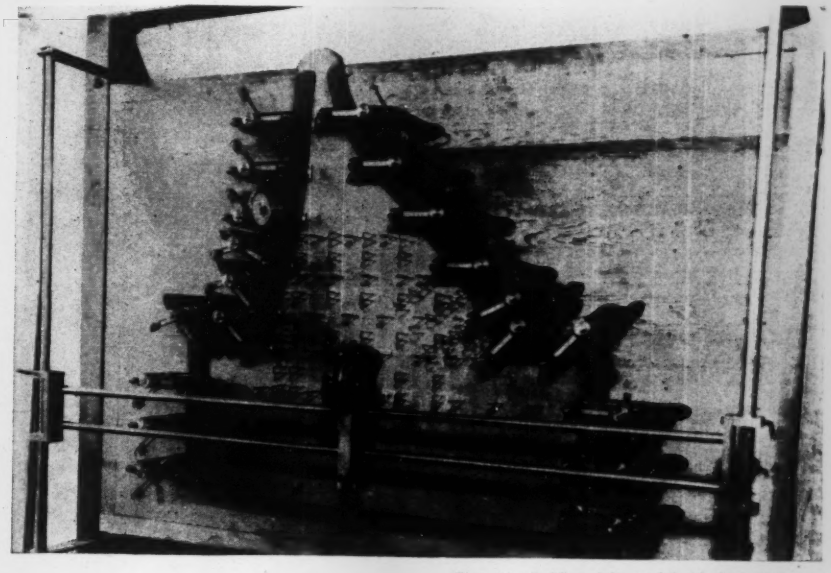


Fig. 33—Rubber-slab model of dam cross-section equipped for deformation tests. Pins are arranged for measurements on horizontal, vertical and inclined planes.

as during the long construction period.

Other problems included in the concrete research program include the more usual tests of ultimate compressive stress, permeability, long-time masurements of flow, determinations of Poisson's ratio and the modulus of elasticity, tests of sliding friction, strength of bond at horizontal construction joints, comparative ultimate compressive strengths shown by cylinders of different size, variations of strength with age and curing temperature, proper gradation of fine and coarse aggregates, effects of vibrating fresh concrete, determination of proper mix, etc.

The concrete research program has required the establishment of two large adequately equipped concrete laboratories at Denver, the development of new testing equipment for use in the thermal research, and the installation of a 4,000,000-lb. hydraulic compression-testing machine, capable of handling and testing compression cylinders up to 3x6 ft. This machine, obtained in cooperation with the United States Bureau of Standards, has been installed in the basement of the new Custom House Building at Denver.

A part of the cement and concrete research program is being carried on at the University of California under a cooperative agreement between the Bureau of Reclamation and the university. This part of the investigations will include a study of 88 different laboratory and commercial cements. It will include studies of effects of chemical composition, fineness of grinding, and, to a limited extent, manufacturing processes, upon heat generation, strength properties, volume changes and durability, the primary purpose being the selection of cements suitable for the construction of Hoover Dam. Several California cement companies are cooperating in this investigation, which is a continuation of the preliminary work done at the United States Bureau of Standards at Washington.

The cement studies thus far completed have made possible the drafting of tenative specifications for portland cement, for use in Hoover Dam; and have indicated which of the cements tested have favorable characteristics (*ENR*, Nov. 10, 1932, p. 558). Ultimately the most promising cements will be further tested in the Denver laboratories for temperature rise, volume changes, and elastic and plastic properties.

Hydraulic research

The unprecedented conditions of high head and large quantities of water to be released at Hoover Dam present unusual hydraulic problems. These are being solved by the construction and testing of small-scale models. Sometimes models of two or more different scales are built and tested in order better to establish the similitude between the models and prototype.

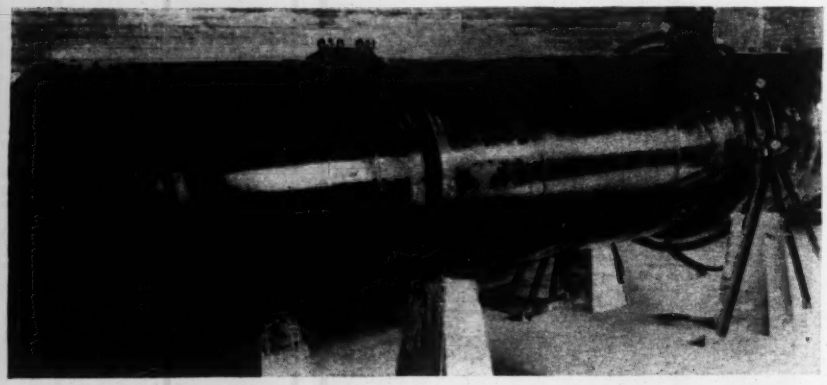


Fig. 34—Tests on penstock-pipe models resulted in great savings in metal. Illustration shows Tuckerman optical strain gages mounted for observing strains in the pipe shell. Flanges of stiffener rings have been removed.

The greater part of the hydraulic model work is being done at the Colorado Agricultural College, in the hydraulic laboratory maintained by the United States Department of Agriculture. However, some work on larger models is being carried on in a laboratory constructed by the Bureau of Reclamation on the Uncompahgre project near Montrose, Colo.; and some tests of the resistance of concrete surfaces to erosion under high velocities were made at a small experimental plant installed on the North Platte project at Guernsey Dam, near Guernsey, Wyo.

Spillways—On account of the height of the canyon walls and the height of the dam, which necessitates a maximum drop in water surface of about 530 ft., neither of the usual types of spillway, in which the flow is allowed to pass over the dam or through a channel at the end of the structure, was considered feasible. It was found necessary to provide for passing the spillway discharge through two tunnels in the canyon walls, one on each side of the river. The discharge to be provided for was fixed at 400,000 sec.-ft., or 200,000 sec.-ft. for each of the two tunnels. Should a flood occur of sufficient volume to require the full capacity of the spillways, the energy of the falling water would be approximately 25,000,000 hp., the flow over each spillway would be about the same as the flow over Niagara Falls, and the total drop would be more than three times as great. For these conditions the velocity in the tunnels would be about 175 ft. per second, or 120 miles an hour.

Models of several types of spillway were constructed, including two general types of side-channel spillways, with and without gates and with gates of different types installed at different locations. The type of spillway best adapted to all conditions was found to be a side-channel spillway with the discharge controlled by drum gates installed along the crest. In this type of design the water must flow over the wair, then make a 90-deg. turn and flow down the channel that runs parallel to the weir, finally entering the inclined shaft leading to the spillway tunnel. The problem involved, therefore, was comparable to making a great falls like Niagara turn at right angles and flow through a 50-ft. inclined tunnel.

The spillway model tests showed conclusively that analytical design methods, based on fundamental hydraulic laws, have not thus far been developed to the stage where they can be depended upon to give satisfactorily accurate results in the case of side-channel spillways of such unprecedented magnitude. Model testing was found to be the only possible method of designing the side channels so as to obtain satisfactory flow conditions. In this case the research program can be credited with exceedingly important improvements in design in addition to economies totaling about $500,000.

Erosion Tests—On account of the unusually high velocities that will occur in the concrete-lined spillway tunnels and in the tunnels below the tunnel-plug needle-valve installations, tests were made to determine the resistance of concrete surfaces to erosion under high velocities. Concrete blocks, cast with various surface characteristics, were subjected to the action of a continuous stream of water issuing from a 1-in. nozzle at velocities of 100 to 175 ft. per second inclined at various angles to the blocks and maintained against individual blocks for periods as long as 34 days. The results showed the feasibility of constructing concrete lining capable of resisting erosion under the velocities to be experienced but emphasized the importance of smooth surfaces and good alignment.

Intake towers

All water that will be released at Hoover Dam, except the flow over the spillways, which will occur only at infrequent intervals, will be controlled at four intake towers, each tower being about 390 ft. high and from 67 to 82 ft. in outside diameter. Two sets of openings, one near the bottom and the other near the middle, will be installed in each

tower, each set of openings being controlled by a cylinder gate 32 ft. in diameter. In case of emergency it may be necessary to close the lower gates under heads of more than 300 ft.

In order to investigate the hydraulic-flow conditions, the vacuum conditions, and to determine the shape of openings required to minimize the losses of head, a model of one of the intake towers was constructed on a scale of 1:64. The tests pointed the way to improvements in the hydraulic design and showed that the extensive air vent systems that had been proposed are not necessary. The intake tower model research can therefore be credited with the saving of pipe and other metal work valued at approximately $140,000.

Pipe losses

All the steel penstocks and outlet pipes which lead from the gate towers to the turbines and outlet valves are combinations of straight lengths of pipe, with bends, branches and reducers, all of unprecedented size. A model of one of the pipe systems was constructed in conjunction with the gate-tower model, and flow conditions, losses and other information was secured by means of pressure measurements. A transparent model of one of the branches was also built and tested, so that the flow conditions could be visually observed. The results of these tests indicated somewhat smaller losses than had been calculated from the tests made at the hydraulic institute of the Technische Hochschule, München, under the direction of Dr.-Ing. Professor D. Thoma.

Needle valves

Needle valves will be used to control the discharges from the reservoir not utilized for power development. Those in the canyon wall will discharge in the open. However, those in the tunnel plugs will be located a considerable distance from the tunnel outlets and consequently will discharge into an inclosed space. The needle-valve installations in the tunnel plugs are being made in order to effect an appreciable economy in the cost of the steel-plate outlet pipe and in order to avoid spray conditions for a substantial part of the outlet capacity on account of the high voltage at the power plant. Six 72-in. needle valves are required in each outlet, each valve being capable of discharging a maximum of 3,670 sec.-ft. at a velocity of about 175 ft. per second. It is important that the six valves in each outlet be arranged so that the jets will not be concentrated at one point and so that disturbances in the tunnel will be avoided as far as possible.

Two models of one set of tunnel-plug valves were built and tested, one on a scale of 1:106 and the other on a scale of 1:20. The actions of the two models were very similar, and the results of the tests permitted the selection of an arrangment that minimizes the flow disturbances and erosive tendencies. The results of this research showed that the comparatively large air-vent tunnels that had been planned are not necessary, thus saving the cost of these tunnels, about $30,000.

Outlet-pipe design

One of the outstanding problems in connection with the design of the dam and power plant was the transmission of water from the reservoir to the turbines in the power plant and to the needle valves in the outlet works. Under the severest conditions as to water-hammer, the conduits will be required to withstand internal pressures of about 300 lb. per sq.in. Each turbine under minimum reservoir elevation will require a flow of 2,075 sec.-ft. of water at full gate opening. With maximum load on four turbines and with full release from the needle valves in the outlet works, each of the four conduits will discharge approximately 33,400 sec.ft. No precedent existed for handling the quantities of water involved under such high pressures. It was found infeasible, because of lack of room between the canyon walls, to bring the penstocks through the dam and distribute water to the turbines in a satisfactory manner. Two of the four 50-ft.-diameter diversion tunnels are required for spillway purposes. The other two will be used for power and irrigation-water outlet purposes and will be supplemented by two 30-ft.-diameter tunnels placed at the highest feasible elevation consistant with the operation range of the water surface in the reservoir.

Consideration was first given to concrete-lined pressure tunnels in rock. An analysis of the stress distribution in the rock surrounding the tunnels, however, disclosed zones subjected to tensile stresses along which fractures might occur and leakage develop when the tunnels were under pressure. Leakage into the abutments of the dam and into seams and fissures in the canyon walls below the dam, at the very high pressures involved, would be objectionable and dangerous. It is not economically feasible to reinforce the concrete tunnel lining positively to prevent leakage. Studies were next made of the possibilities of placing welded-steel linings in the tunnels to prevent leakage. These studies disclosed that if the steel lining were made thick enough to resist being breached by the expansion of the tunnels when under full pressure, the amount of steel necessary would be sufficient to construct a penstock 30 ft. in diameter and of thickness to withstand the full hydrostatic pressure.

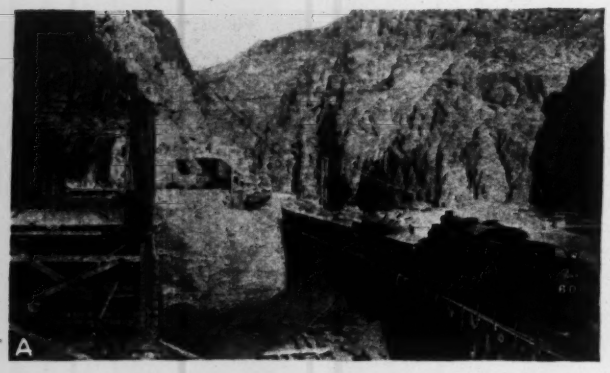
As a result of these studies the decision was made to install 30-ft.-diameter plate-steel penstocks of high elastic-limit material inside the 50-ft.-diameter tunnels and to construct the upper tunnels of sufficient diameter to provide the required space around the outside of the penstocks in these tunnels. This construction insures full strength and water-tightness and will provide access at all times to the outside of the pipes for inspection and maintenance purposes. The problems involved in the manufacture, fabrication and installation of plate-steel pipes of this large diameter and under the existing conditions are without precedent. As the most serious problems are essentially manufacturing and fabricating problems, the specifications were issued for both the manufacture and installation of the pipes, leaving many of the details of design, manufacture and installation for determination by the contractor. Prior to award of the contract and subsequent thereto the contractor, The Babcock and Wilcox Co., has carried on a very comprehensive program of research, including extensive testing of models to destruction, for determining stresses and details of design. These tests have been supplemented by other model tests and exhaustive analytical research conducted by the engineers of the bureau at Denver, Colo.

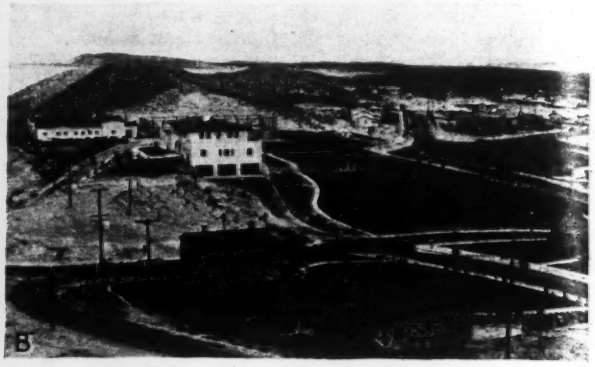
The special studies and model tests conducted by the Bureau of Reclamation and The Babcock and Wilcox Co. have resulted in reductions aggregating 7,400,000 lb. of metal due to various important changes in the specified designs, such as increased spacing and reduced dimensions of the stiffener rings, supports and butt-strap joints. These changes with other reductions effected a saving of nearly $900,000 in the cost of the steel penstocks. This is directly attributable to the research investigations. Another tangible saving in weight of metal in the penstocks creditable to research is the reduction of 1/8 in. in the thickness of the steel plate in the penstocks based on exhaustive investigations of water-hammer stresses. This effected a reduction of nearly 3,800,000 lb. of metal, with a corresponding saving in cost of nearly $450,000. The total estimated saving in cost of steel pipes directly creditable to the research program is approximately $1,500,000. In all, the program is credited with savings of $2,170,000 to date, effected at a relatively small cost.

Summary

Only a very brief outline has been given of the investigation, research and testing work being carried out to insure the safe and economical design of Hoover Dam and appurtenant works. The results thus far obtained have been gratifying in the extent to which they have confirmed and supplemented existing theory and practice. In the fields where original research has been necessary the information obtained has been invaluable in determining the proper design and construction of Hoover Dam, and this information will be of great value in future work of similar proportions.

Last-Minute Views at Hoover Dam





A: Dumping fill material for cofferdam construction. Bridge at left will carry railroad to dam site over tops of upper portals of Nevada diversion tunnels.

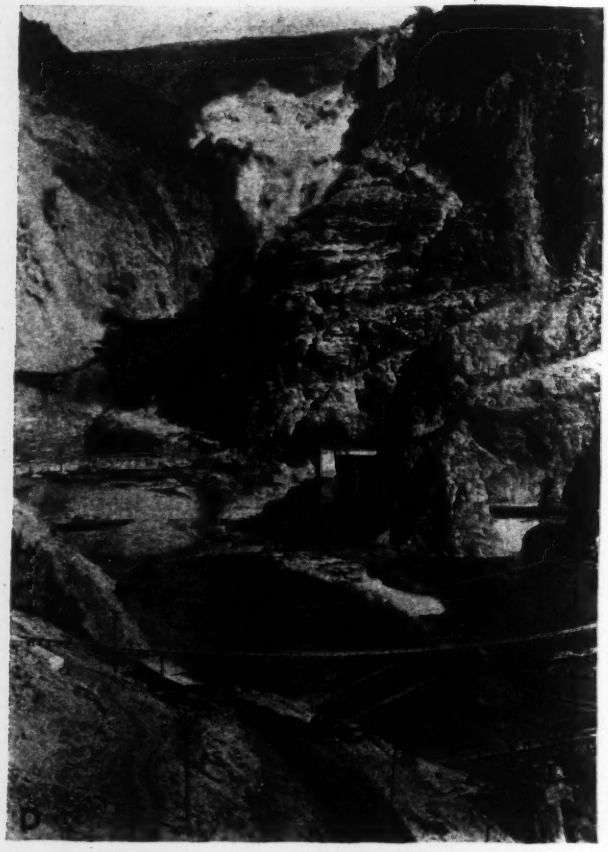
B: This attractive section of Boulder City is the administration building area.

C: Canyon wall scalers at work 550 ft. above the river at the site of the Arizona intake towers.

D: Two Arizona tunnels are now carrying entire flow of Colorado River. The blast is part of canyon wall-scaling operations.

E: Building the earthfill upper cofferdam. Large boulders in riverbed prevented driving of cut-off sheetpiles, which were placed in concrete footing in trench excavated to rock.

F: The government built this fine school for Boulder City's children. The contractor supplies the teaching staff.



Letters to the Editor

Depression Economics

Sir—In your issue of Nov. 3, p. 535, Daniel B. Luten raises several points in regard to my previous letter. Without trespassing further on your valuable space, may I suggest that all engineers interested in the cause and cure of the depression read the following three articles? (1) "The Fallacy of Profits," by Henry Pratt Fairchild, *Harpers'*, February, 1932; (2) "The Balancing of Economic Forces," by the committee on the relation of consumption, production and distribution of the American Engineering Council, *Mechanical Engineering*, June, 1932; (3) "The Irrepressible Conflict: Business vs. Finance," by David Cushman Coyle. This last is written by one of our own profession, a consulting civil engineer in New York City, and may be obtained by writing him personally at 101 Park Ave. I believe that these three articles will answer all the points raised by Mr. Luten.

RALPH W. POWELL.
Ohio State University,
Columbus, Ohio.

Unprecedented Percolation Record

Sir—The article on the Ringedal Dam, in your issue of Oct. 27, discloses a leakage condition for a concrete structure which, so far as I am aware, is unprecedented. It is indicated that, on account of the cracks in the stone facing of the dam, water readily reaches the core concrete through which it percolates, but there is no reference to possible cracks in the concrete or to construction joints that are not tight, along which water under pressure might find easy passage. It is further indicated that during 1929 the leakage amounted to 51,000 cu.m. per day, of which 85 to 90 per cent went through the dam proper, the remainder being leakage along the base. For a submerged dam area of 7,300 sq.m., and using the lesser figure of 85 per cent, this means a percolation rate through the concrete of 19.5 ft. in 24 hours.

Such a rate seems entirely incredible as it would be a high rate even for a relatively porous earth formation. Meager concrete is of course permeable, but not to the extent here shown; and rich concrete, even under high pressure, is almost impermeable. The above figures are so high as to suggest possible error in the record, the existence of cracks and construction joints along which leakage would occur rather than percolation through the body of the concrete, or such a condition of disintegration in the concrete as to call for a long careful analysis of loads and stresses on the masonry. The thin concrete diaphragm in front of the dam is an ingenious device that should prevent further percolation through any deterioration of the main body of concrete, but it will not relieve the dam of its loading. I strongly suspect that the major leakage is through undiscovered cracks and defective construction joints.

Seattle, Wash.,
Nov. 4, 1932.

JOSEPH JACOBS,
Consulting Engineer.

Strength of Clay

Sir—I have been very favorably impressed by the excellent discussion by Arthur Casagrande published in *Engineering News-Record*, Aug. 11, 1932, p. 159, and by his interesting hypothesis concerning the difference in the physical properties of clay in disturbed (remolded) and undisturbed state.

I am afraid, however, that the settlements computed by Mr. Casagrande for pile foundations actually would not be so considerable as they are represented in Fig. 4 (b) and (c), reproduced here as Fig. 1. Although allowance for both undisturbed and partially disturbed material has been made, the settlements have been computed on the assumption of thoroughly kneaded material as it is prepared in the laboratory. Personally, I believe that even in sections close to the pile there is only imperfect mechanical kneading of the clay, and that the decrease in its strength should be attributed to a great extent to the phenomenon of "thixotropy," explained below.

Colloidal matter may take the form either of jelly-like gels, as undisturbed clay often does, or that of sols (like a liquid). There are gels, which being vigorously shaken, liquefy to form a sol; but when kept, the sol gelates once more.

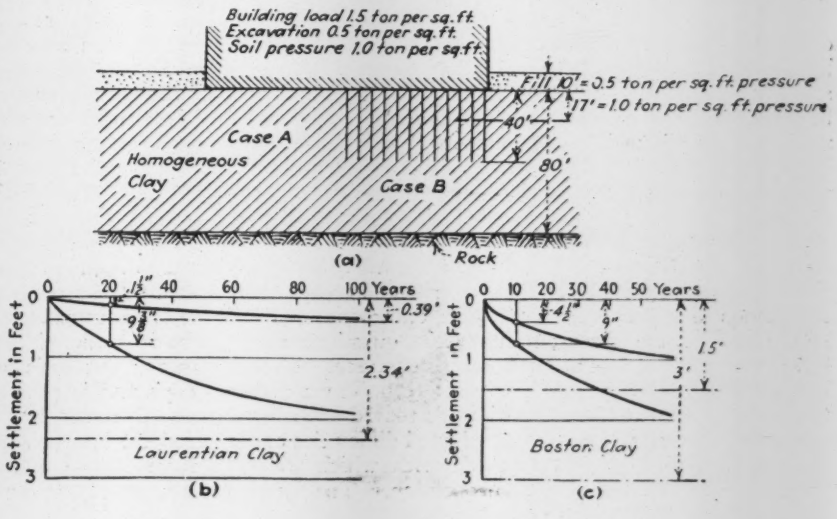


Fig. 1—Time-settlement curves for raft and pile foundation in clay.

My opinion is that possibly this is the clay behavior in piledriving and after it. The phenomenon of thixotropy suggests (I am quoting a chemical work) that "the properties of the gel are dependent on the preservation of a particular structure or mode of cohesion of the particles and that this structure is

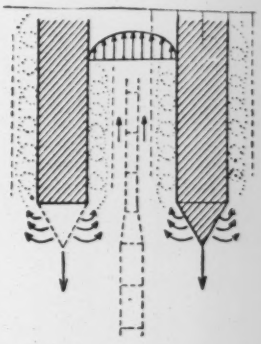


Fig. 2—Remolding action in clay displaced by driving piles.

destroyed by agitation, the normal coagulation being restored after a period of rest." (Hedges, "Colloids," p. 198. London, 1931.) These words, except the final, are practically the same as those of Mr. Casagrande in his conclusion I.

There is no difference of opinion about the uselessness of piledriving in solid clays. But I believe that that part of the remolding effect caused by the pile, which is due to the thixotropic phenomena, disappears relatively soon, while Fig. 4 (b) and (c) presume that the clay remains remolded during 50 or 100 years.

Fig. 2 (Mr. Casagrande's Fig. 5) recalls the upward deflection of a foundation beam under the action of the negative bending moment; possibly such a deflection actually takes place in addition to the remolding effect.

DIMITRI P. KRYNINE,
Research Associate in Soil Mechanics,
Yale University.

New Haven, Conn.,
Oct. 30, 1932.

Engineering News-Record

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Hoover Dam's First Stage

WHEN the channel of the Colorado River in Black Canyon was successfully closed in mid-November, an achievement of unique character and difficulty was brought to completion. Down in the deep-cut gorge of the remarkable river, infrequently visited by man, the first of the three great stages of Hoover Dam construction has been carried out, under difficulties rare in engineering annals. Two tunnels of giant proportions have been pierced through either canyon wall for nearly a mile in length, and the river flow has been turned through them; and this after only twenty months of work, instead of the scheduled two and one-half years. The successful undertaking erects a milepost in construction history. For this reason the present issue is devoted to a summary of the work done and its antecedent history, as a compact record for information, reference and file. It is our hope that at the completion of Stage 2, the foundation construction, and Stage 3, the concreting of the body of the huge dam, similar issues will be published and thereby make available a comprehensive account of one of the greatest engineering undertakings since the days of the pyramid-builders. The brilliant success of the first stage is due in equal measure to the engineers of the Bureau of Reclamation and the contractors, Six Companies, Inc., to their foresight, their wisdom of planning and their driving energy. In extending to them our congratulations, we also acknowledge with pleasure the friendly cooperation and help that made possible the timely publication of the present issue.

Significant Research

THE construction operations at Hoover Dam site require no present review or appraisal. The work itself is its own best commentary. But a word is in order to draw special attention to the extensive research that is being carried on in the effort to make the construction safer, better and cheaper. The astonishingly broad scope of the researches as disclosed in a special article in this issue is both unexpected and impressive. Mere statement of the problems to be solved, however, affords convincing evidence of the necessity for the work. The truth is that in every corner of the field of engineering there remain unexplored questions, which in ordinary cases can be well enough disposed of by practical allowance but which become critical in work that transcends the proportions of past experience. Even here some of the research into these questions might have been omitted, but at large cost. The research work has already paid a profit—in terms of millions rather than thousands of dollars. While this record of profit is sensational because of the unprecedented difficulties of the undertaking, all technical research with which we are familiar is profitable in due proportion. The present large-scale demonstration of the value of research gives this fact an emphasis which it richly deserves and strengthens the expectation that research in civil engineering problems will gain increasing support, to the profit of the community whose investment of labor and savings in construction is made more fruitful through its aid.

The Tide Turns

THE LOT of the industry association over the past two or three years has been a difficult one. From a place of eminence and authority in its industry, many an association found itself shifted almost overnight to the position of a poor relation. Praised and supported in good times, it was cast adrift as useless in a storm. But the wages of adversity are sometimes worth while, and if present indications are significant the industry association is coming back as a more potent force than ever before. Last week the American Institute of Steel Construction announced the signing of seven new members, among them the fabricating units of the two largest rolling mills, which have never before been identified with the institute as actual members, although supporting it financially. The development is immediately reflected in the reinstatement of five of the institute's district engineers. Important in itself, this development is more significant as symbolizing a rebirth of cooperation and industry-consciousness that has every appearance of being real. The Portland Cement Association has recently also experienced a similar revival of team play. Thus to the spirit of self-help that the depression has engendered has now been added that of cooperative enterprise. No more hopeful portent of business recovery has yet appeared than the rejuvenation of two of the largest and most influential industrial groups that serve construction. The future soundness and stability of industry depend on the labors of such associations.

Roadbuilding in Jeopardy

ACCORDING to the budget presented to Congress last week, federal construction may be reduced sharply in the next fiscal year. Public buildings and highway construction in particular are to be curtailed severely. As to the former, the recommendation was not unexpected, for the prodigious schedule of departmental building construction in Washington and of post-office and court-house construction elsewhere that was adopted some years ago is nearing its end, leaving few major needs for the present. The discontinuance of highway-building activity, however, has no such explanation. We are far from completion of the federal-aid network, and farther still from the point at which the technical coordination and helpful guidance of state operations obtained through the federal-aid system ought to be dispensed with. If President Hoover's recommendation means abandonment of the policy of extending federal aid to highway construction, it is of momentous significance and merits painstaking study by Congress before it is approved. No doubt the states have the principal interest and obligation in developing the highway network; but a federal interest has existed since earliest days and is greatly heightened by the traffic conditions and demands that have developed in recent years. This federal interest, which is still growing strongly, should have careful thought before highway policy is changed. Transportation has important national aspects, and their

proper consideration speaks against relinquishment of that partnership in highway development which the budget recommendation foreshadows.

Give Thought to Relief!

FUNDS are needed by all the organizations that are attempting to help engineers who are out of employment. A recent check of engineering employment conditions indicates that there are few places where conditions will be better this winter than last winter; in most centers conditions are expected to be worse. Money is needed now and will be needed regularly all winter. Though most employed engineers have less this winter than last, nevertheless most of them still can give *something*. If every man who has a job will give regularly, even though the amount must necessarily be small, the neediest cases at least can be cared for.

Government Reorganization

EXCELLENT proposals for reorganization of the federal government are outlined in President Hoover's message and proposed executive orders of December 9. They offer the most promising as well as most far-reaching revision of government bureau relations within memory.

One cannot fail to be impressed with the well studied and courageous nature of the orders. The rearrangement is consistent and brings into logical relationship many activities heretofore scattered in separate departments and bureaus. Independent boards and offices have proliferated like warts on the body politic, and many of these are now brought into the normal departmental structure or are wiped out. With reasonably efficient operation the reorganization should yield large returns in economy, coordination and elimination of delays and conflict. Inevitably it disturbs many well-crystallized habits and offends some personal preferences, but these difficulties must be faced in any change of governmental mechanism.

It is interesting to observe that the rearrangement is by no means strictly functional in the narrow sense. Survey work, for example, is not centralized in one office. Or again, the construction operations of the Bureau of Indian Affairs and of the Park Service are not assigned to public works but go to a separate division of the Interior Department. A broader grouping of related types of activity is contemplated in the President's proposals, aiming at simplicity of action.

To the engineer the three great features of the reorganization are the creation of a public-works division, a land-utilization division and a merchant-marine division. The latter two are relatively simple. Establishment of a public-works division completely overshadows them in importance and in interest.

This public-works division is to unite under centralized control all but a small residue of federal public-works operations. It is to include the Geological Survey and the Reclamation Bureau (already in the Interior Department) and in addition the Supervising Architect's office (Treasury), river and harbor construction (War), the Mississippi River Commission (War), and the Bureau of Public Roads (Agriculture). The aggregate of the operations of these offices measured in money is very great, but even greater is the range in character of the work included. No organization having a like breadth of civil engineering and architectural activity has ever existed, at least in this country and possibly anywhere in the world.

Inclusion of the river and harbor work and of the Bureau of Public Roads in this grouping will probably be the principal stumbling block to Congressional approval of the public-works division. The long tradition under which the engineers corps of the army has had exclusive control of river and harbor work and actual though not nominal control of the Mississippi River Commission constitutes an important obstacle. The memorandum that accompanies the President's message presents the reasons for disregarding this tradition, in briefest possible form:

> River and harbor and flood-control work . . . is related to national defense in only the most indirect manner. Originally . . . the War Department was the only government establishment system which possessed a group of engineers of sufficient size and training to prosecute the work satisfactorily. The prosecution of river and harbor improvements and flood-control work under the Corps of Engineers has necessarily resulted in the expansion of the officer personnel of that Corps beyond the point to which it would normally have grown if its field of operations had been confined to strictly military activities. This river and harbor and flood-control work is similar to and should be grouped with other public works and construction activities.

This is a plain and strong statement of reasons for the change. Doubtless the Congressional hearings on the executive order will bring out a corresponding statement of reasons for retaining rivers and harbors under War Department jurisdiction. The army engineers have made an enviable record of efficiency and of independence of political considerations. It is urgently desirable that the present opportunity be taken to set forth in full all sides of the question so that it may be soundly and finally disposed of.

On the transfer of the Bureau of Public Roads from the Agriculture to the Interior Department also, a convincing piece of reasoning is presented, but again there is another side, which Congress should bring out and consider. By virtue of its position in the Agriculture Department the bureau has been in high degree independent, and its technical administrators were left free to carry out their often highly difficult supervision of federal-aid work with no interference by political pressure. The Interior Department, on the other hand, has, during a long period of years prior to the present administration of Ray Lyman Wilbur, been involved in many political demands and controversies. Were the Bureau of Public Roads to be exposed to political influence, the result would be disadvantageous to the country at large.

In short, if the transfer of either Public Roads or Rivers and Harbors to the Interior Department involves the hazard of politics, then it would be better to sacrifice organizational logic and retain the more important element of upright independence. But there is no insuperable reason why the Interior Department cannot be removed from the political sphere and be made to furnish as favorable conditions for the functioning of these offices as they now enjoy.

More than twenty years' study, discussion and planning lie back of the departmental reorganization proposed by the President. In the light of this long history and the well-studied soundness of the recommendations made, it is to be hoped that the executive orders will be approved by the Congress in their essential features. Whether or not the short session permits them to go into effect, they will stand as a real contribution to proper organization of the governmental structure.

NEWS OF THE WEEK

$2,350,000 Loan To Complete Dam Approved by R.F.C.

A LOAN of $2,350,000 at 5 per cent interest to the city of San Diego, Calif., for the completion of El Capitan dam, a new unit in the city water supply system, and for the construction of a pipe line between the dam and the city, was approved by the Reconstruction Finance Corporation on Dec. 12.

Other loans approved by the corporation were $175,000 to the trustees of the Arkansas State Agricultural and Mechanical College, Jonesboro, Ark., for the construction of two dormitories; a loan of $180,000 at 5½ per cent interest to the city of Winston-Salem, N. C., to extend the city's sewerage system; a loan of $22,000 to the Tybee Water Works (a private corporation), Savannah Beach, Ga.; a loan of $100,000 at 6 per cent to the city of Tyler, Texas, for additions to its sewage disposal plant. On Nov. 30 a loan of $78,000 at 6 per cent to the town of Valdese, N. C., for a new sewer system was approved.

The El Capitan dam of San Diego is now partly completed. The R.F.C. money ill be used to complete the dam and to lay six miles of 48 in. and two miles of 36 in. pipe in the 25 mile pipe line included in the project.

The loan to the Arkansas State College is based on the filing of a new application in which the loan is declared to be a general obligation of the trustees. State legislation will be necessary to permit the trustees to become a party to such a transaction. The loan would bear interest at 5½ per cent payable in 24½ years. The state legislature convenes on Jan. 9.

Loan applications

The county commissioners of Allegheny County, Pennsylvania, have applied to the R.F.C. for a loan of $2,000,000 to replace Brown's Bridge over the Monongahela River at Homestead, Pa. It is expected that the bridge will be made a toll bridge in order to obtain the R.F.C. loan.

The Brownsville (Texas) Navigation District expects to apply to the R.F.C. for a loan of $1,500,000 for the Brownsville deep-water ship channel and port development work. The project includes a channel 100 ft. wide and 25 ft. deep from the jetties to a point within four miles of the city where there will be a 1,000 ft. turning basin and terminal facilities.

Other applications for loans are as follows: Charlotte, N. C., for $25,000 for an abattoir, $40,000 for a swimming pool, and an amount not yet stated for extending the water system of Charlotte to serve Pineville, N. C. Application for a loan for the construction of a water plant in Gretna, La., is to be made to the R.F.C.

A new move to obtain R.F.C. funds for the construction of the Grand Island bridges at Buffalo is to be made according to the counsel for the Niagara Frontier Bridge Commission.

Tunnel Contract of $7,331,815 Let for Los Angeles Aqueduct

Contract for the construction of the 12.7 mile San Jacinto tunnel, the first major unit of the Colorado River aqueduct, was awarded Dec. 12 by the Metropolitan Water District of Southern California to the low bidder, Metropolitan Engineering Corporation. The actual award figure of $7,331,815 is slightly less than the announced bid due to alternative provisions. Details of the bidding were given in last week's issue, p. 696. Execution of the contract will be completed by the district when several minor requirements have been met.

The Reconstruction Finance Corporation as the only bidder purchased the first block of $2,016,000 bonds offered by the district.

Beginning of active work is threatened by a petition filed by organized labor asking court review of the wage scale adopted by the district.

Municipal Engineers in Chicago Form New Organization

Thirty members of the American Society of Municipal Engineers in the Chicago metropolitan area formed a Chicago chapter on Dec. 6 following a preliminary meeting June 9 called by S. A. Greeley, vice-president and W. W. DeBerard, director.

T. Chalkley Hatton, consulting engineer, Milwaukee Sewerage Commission, and chairman of the unemployment committee of the Milwaukee Engineers Society, told of canvassing the engineers of Milwaukee to learn of actual need for assistance, since the society has some $5,000 and proposed to loan engineers $25 per month. Out of a list of more than 1,000 only 3 have so far made application as being in extreme need. George W. Tillson, one of the oldest members of A.M.E. and at one time its secretary, recounted early experiences in New York.

C. W. S. Sammelman, executive director, St. Louis, Mo., spoke on the engineers' present-day predicament of being in the limelight by reason of the drive toward a reduction in public expenditures. To educate the public to the necessity of improvements and their subsequent operation the chapter in St. Louis holds meetings to which it invites heads of civic organizations, service clubs and improvement associations. A mailing list of more than 1,000 receives notice of sessions at which heads of engineering departments describe the more interesting phases of the works being built and services rendered. Mr. Sammelman stated that the parent society had added members continually throughout the year at the rate of fifteen per month. Losses are about one per month. Toronto is about to organize a chapter.

Officers elected for the ensuing year are as follows: President, Charles E. DeLeuw; vice-presidents, E. T. Howson and Dudley C. Meyers; secretary-treasurer, J. W. Nemoyer, Tower Building, Chicago.

Large Reduction in Federal Work Proposed in Budget

REDUCTIONS in federal expenditures amounting to many millions were proposed to Congress by the President in his message transmitting the budget for the fiscal year ending June 30, 1934. The total appropriations recommended are $830,000,000 below the appropriation for the current fiscal year ending next June. The total budget figure is $4,403,000,000. If modifications recommended in the budget message are put into effect this will be reduced to $4,219,000,000.

Reductions in federal expenditures of special interest to the construction industry are as follows:

Highway funds reduced

The appropriation for federal aid highway work is cut to $40,000,000 of the $51,560,000 still unappropriated of federal aid authorized by Congress. On this subject the President said: "I earnestly recommend to the Congress that there be no further grant of legislative authority for appropriations for federal-aid highway until the financial condition of the Treasury justifies such action. The annual program of federal aid for the highway system was increased from $75,000,000 to $125,000,000 beginning with the fiscal year 1931, and has been materially further advanced within the last two years by the appropriation of $80,000,000 made in the Emergency Construction Appropriation Act of December, 1930, and the appropriation of $120,000,000 contained in the Emergency Relief and Construction Act of July, 1932. I am not unmindful that these emergency appropriations, amounting to $200,000,000 represent advances only to be reimbursed to the United States by deductions from the apportionment which may be made to the states under any future authorizations that may be granted for carrying out the federal highway act. I do not, however, view this as a commitment which of itself necessitates further authorization for federal appropriations until such time as the financial condition of the Treasury justifies such action."

Public building program

Of the $700,000,000 for the federal public building program authorized in 1926, the funds available for expenditures in the fiscal year ending June 30, 1933, amounted to $134,000,000 and the emergency relief act added $100,000,000. The budget for 1934 is $60,000,000 which will be added to what remains of the $234,000,000.

The Treasury Department budget is cut by $148,000,000 for the construction of new federal buildings because of the money provided under the public building program and the Relief Act.

The item for the Coast and Geodetic Survey is cut from $3,650,000 to $2,300,000. The cut is largely accounted for by the

appropriation of $1,250,000 in the Relief Act.

The budget figure for forest roads is cut from $8,905,000 to $6,457,000 and no provision is made for national-forest highways to offset the emergency construction authorization of $5,000,000 in 1933.

Bureau of Reclamation

A net increase of $684,000 is shown in the budget for the work of the Bureau of Reclamation, exclusive of the Hoover Dam project. Regular and emergency appropriations for Hoover Dam amounted to $23,000,000 for the fiscal year 1933 and the budget for 1934 is $10,000,000.

An increase of $400,000 is shown in the budget figures for the geological survey.

In the construction work of the Quartermasters Corps the total decrease amounts to $17,400,000.

An item of $4,000,000 is provided in the 1934 budget for construction work on Madden Dam in the Canal Zone; $4,500,000 was included in the 1933 budget.

River and harbor work

The amount for rivers and harbors is cut from $60,000,000 for 1933 to $40,000,000 for 1934. The relief act added $30,000,000 to the 1933 amount, part of which may be carried over to 1934. With cash on hand included, the average for the two years will be about $75,000,000.

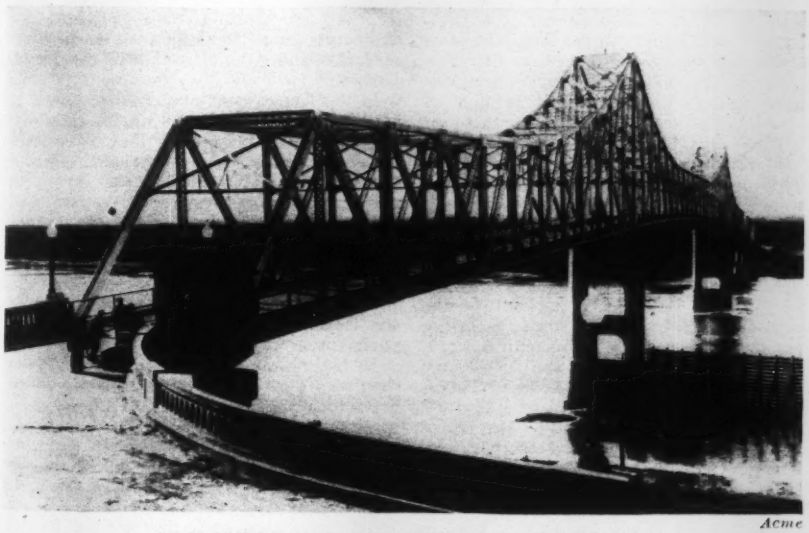
The flood control figures for 1934 are increased to $19,700,000 as compared with $12,100,000 for 1933 and the amount for the Sacramento River work is increased from $207,000 to $768,000. An amount of $15,500,000 was added to the Mississippi River flood control money by the Relief Act and with cash on hand the average for the two years will be over $42,761,000 per year.

Reduction of Taxing Agencies in Illinois Proposed

Savings of $15,000,000 in schools and highways alone in 101 Illinois counties outside of Cook County are possible were the governmental structure revamped in accordance with a report made to the local government committee of the state legislature by Griffenhagen and Associates. It is recommended that state construction and maintenance be carried out on all bond issues and state aid systems, local public roads and city streets that are connecting links with state systems. It is proposed to eliminate the offices of county highway superintendents and local highway commissioner. Some 3,700 downstate governmental units control roads, building and maintenance.

Two hearings have been held by the local government committee in Chicago at which much interest has been displayed. Prof. C. E. Merriam, University of Chicago, who has been deputized by a group, headed by the mayor of Chicago and governor-elect of the state, to prepare a program of legislation to reduce taxing agencies in Cook County, urged that consideration be given to the formation of a separate state for the Chicago Region, and as a preliminary that interstate compacts be sought between Illinois and Indiana on governmental activities that cannot be restricted to political boundaries. A public policy referendum on the subject is suggested.

Prof. A. R. Hatton, Northwestern University, approved the Griffenhagen report in principle, stressing the desirability of keeping within statutory limitations in reassignments and consolidations. The report recommends doing this in a series rather than making wholesale changes.



Acme

NEW BRIDGE OVER MISSISSIPPI RIVER COMPLETED

A new highway bridge across the Mississippi River between Savanna, Ill., and Sabula, Iowa, has been completed and will be opened in the near future as a toll bridge. The structure has a total length of about 2,500 ft. and a main center span of 520 ft. It was built by the Savanna-Sabula Bridge Co.

The bridge is notable as the first structure to be completed as a result of the action of the Reconstruction Finance Corp. in providing funds for self-liquidating projects. While the R.F.C. as yet has not actually put up any money for completion of the bridge, it agreed to undertake to provide $190,000 for the completion of the bridge and in this way made it possible for the Bridge Co. to obtain temporary financing through private channels. Work on the bridge had been at a standstill for lack of funds for some months when the R.F.C. approved of a loan.

Large Rolling Mill Units Join Steel Fabricating Institute

The American Institute of Steel Construction, it was learned last week, has added seven companies to its membership, including the American Bridge Co. and McClintic-Marshall Corp., fabricating subsidiaries of the U. S. Steel Corp. and the Bethlehem Steel Corp., respectively. In addition to these, the two largest fabricating units in the country, new members include Jones & Laughlin Steel Corp.; Virginia Bridge & Iron Co.; Bethlehem Fabricators, Inc.; Burger Iron Co.; R. C. Mahon Co. It is said that, with these companies included in the membership, practically the entire fabricating tonnage of the country is now supporting the Institute and its program.

In order that the income derived from other members may be comparable to the contributions made by the mill interests (U. S. Steel and Bethlehem) the assessments for the fiscal year ending Oct. 1, 1933, have been raised from 10 to 15 cents per ton. The increased revenue from the additional 5 cents per ton assessment will permit the reinstatement of five district engineers who were laid off during the recent period of retrenchment. It is understood these engineers are Alexander Miller, Cleveland; W. E. Emmett, San Francisco; B. H. Hastings, Philadelphia; Jack Singleton, Topeka; and Henry Penn, Chicago.

Technical Publishing House Celebrates 125th Anniversary

Some 35 engineers, educators and publishers gathered at dinner in New York on Dec. 9 with members of the firm of John Wiley & Sons to celebrate the 125th anniversary of the firm's existence. Congratulatory addresses were made by C. C. Paulding, vice-president of the New York Central Railroad, William Evarts Benjamin, who was an associate of the firm 50 years ago; Dexter S. Kimball, of Cornell University; Theodore Grayson, University of Pennsylvania; F. G. Melcher, editor of *Publishers' Weekly;* A. A. Potter, Purdue University, and others. W. O. Wiley, president of the house and great grandson of its founder, related incidents of the years since Charles Wiley established himself as bookseller at 6 Reade St., New York, eight years before the battle of Waterloo.

In its earlier years the house was engaged in general publishing, bringing out Cooper's "The Spy" in 1821. While some technical books were published in the first part of the century, such as Schoolcraft's "A View of the Lead Mines of Missouri" (1819), and Dana's "A System of Mineralogy" (1844), it was not until about the middle of the century that the house turned mainly toward scientific and technical books. It devoted itself particularly to this field after 1875, when the name of the firm became John Wiley & Sons. Under this name and under the successive direction of John Wiley, the late Major William H. Wiley and William O. Wiley, respectively the son, grandson and great-grandson of the original Charles Wiley, the house has been a leader in the technical book field for more than a half a century.

Stopping of All Road Building Proposed in Massachusetts

Stopping all highway construction in the state of Massachusetts during the year 1933 and the turning over of highway funds to municipalities for relief work has been recommended to the Massachusetts General Court in a report of the special committee on public expenditures. This diversion of highway funds to relief work is one of many recommendations made by the committee for the reduction of government expenses and relief of unemployment. The committee was not unanimous in its recommendations.

High Wind Velocity Recorded in Recent Cuban Hurricane

Wind velocities of 125 miles per hour were recorded at the Weather Bureau Station at Nuevitas, Cuba, in the destructive hurricane which passed over Cuba Nov. 9, and the U. S. Weather Bureau estimates that the gusty hammer-like blows of the wind reached velocities of 200 miles per hour. Precipitation was very heavy but no accurate records are available. The barometric pressure at the center of the storm was 28.85 inches.

The storm was remarkable for the slow rate of travel. While the spiral, counter-clockwise velocity of the wind was terrific, the center of disturbance had traveled only 2,000 miles in nine days prior to its reaching Nuevitas on Nov. 9. The rate of travel increased as the hurricane cleared Cuba, and it reached Bermuda, 1,200 miles to the northeast, on Nov. 12. The increase in travel speed was accompanied by a reduction in wind velocity so that the Bermuda maximum stood at 58 miles per hour.

Association Formed to Support Federal Land Reclamation

The National Reclamation Association has been organized to back the continuance of the federal reclamation policy and to support the requirements for immediate loans to the U. S. Reclamation Bureau's funds sufficient for completing work now authorized. The organization was effected during the recent Western Governors' Conference held in Salt Lake City Dec. 5 and 6. Officers elected include Marshall N. Dana, associate editor, *Oregon Journal*, Portland, president; Sam Stephenson, Great Falls, Mont., first vice-president; W. R. Wallace, Salt Lake City, second vice-president; and A. E. Larson, Yakima, Wash., treasurer. The selection of a secretary-manager was deferred.

The stated objects of the association are:

"To secure the continuance of reclamation as a federal policy.

"To obtain continued support for the Bureau of Reclamation by congressional appropriations in the form of loans to the bureau's revolving funds sufficient to enable the bureau to complete the work now authorized and to provide supplemental storage and supplemental construction where economically feasible for the relief of settlers on occupied irrigation projects."

Movement for the formation of such a Western organization was started some time ago in answer to the growing opposition of Eastern and Mid-Western interests to continuance of reclamation. One of the immediate purposes of the organization is to support the request of the Bureau of Reclamation for further federal loans to its funds in order to carry on authorized work in the face of declining income caused by decreased oil royalties and land sales combined with the recent moratorium granted to settlers on the repayment of construction charges.

The organizational meeting was opened by Governor Dern, of Utah, who outlined his motives and reasons for calling the conference. After the election of officers Elwood Mead, U. S. Commissioner of Reclamation, briefly outlined the situation that reclamation now faces. The organization is to include all irrigation states, and committees were appointed to devise a plan for financing, a legislative program and a permanent constitution. Definite plans were made to provide immediate representation before Congress and to sponsor measures in the coming sessions of the state legislatures memorializing Congress to continue the work of the Bureau of Reclamation.

One of the resolutions passed at the meeting stated that, "we cannot fail to recognize that an emergency exists on reclamation projects comparable to that existing in all agricultural districts. This condition makes necessary some provisions for an extension in the repayment of construction costs commensurate with existing needs."

Federal Construction Activities Affected by Reorganization Plan

THE MAJOR construction and engineering activities of the federal government all are affected in the departmental reorganizations proposed in the executive orders transmitted to Congress by the President last week. Acting under a law passed by Congress last June, the President has provided by these orders for the transfer of certain bureaus from one department to another and for the elimination of numerous independent establishments by transferring their administrative duties and powers to existing federal departments. Unless disapproved by Congress these orders become effective in sixty days after their delivery to Congress. If approved by Congress they become effective immediately.

Division of Public Works

Most important among the orders is one providing for the establishment of a Division of Public Works in the Department of the Interior under the immediate direction of one of the present assistant secretaries whose title is to be changed to that of Assistant Secretary of the Interior for Public Works. To this division is transferred the Bureau of Reclamation, now in the Department of the Interior, and the Geological Survey, also in that department; the office of the supervising architect, now in the Treasury Department; the non-military activities (except the survey of northern and northwestern lakes and the supervisor of New York harbor) of the Corps of Engineers, U. S. Army, including river and harbor work, flood control work, the duties and powers of the Mississippi River Commission, the California Debris Commission, the Joint Board of Engineers for the St. Lawrence waterway, the Board of Engineers for Rivers and Harbors and the Inter-Oceanic Canal Board, now all in the War Department; the activities and duties relating to the construction and maintenance of roads in Alaska, now in the Department of Agriculture; the office of Public Buildings and Parks, now an independent establishment; the duties and functions of the National Capital Park and Planning Commission, the Rock Creek and Potomac Parkway Commission, the Arlington Memorial Bridge Commission and the Commission of Fine Arts. The duties and powers of other lesser commissions also are transferred to the Division of Public Works and all the commissions are retained only in an advisory capacity.

Public Health Service

There is also established in the Department of the Interior a Division of Education, Health and Recreation under an Assistant Secretary of the Interior for Education, Health and Recreation. The principal transfers to this division, of interest to the civil engineering field, are the transfer of the Public Health Service from the Treasury Department, the Division of Vital Statistics from the Bureau of the Census, the National Park Service and the national parks, monuments and cemeteries which are now under the War Department.

In the Department of Agriculture there is established a Division of Land Utilization to which is assigned the Forest Service, the General Land Office and the duties and functions of the Committee on the Conservation and Administration of the Public Domain.

In the Department of Commerce there is established a Merchant Marine Division to which is transferred the Coast and Geodetic Survey, the hydrographic office of the Bureau of Navigation, the survey of northern and northwestern lakes, the supervisor of New York Harbor, the United States Shipping Board Merchant Fleet Corporation, the Inland Waterways Corporation and the Bureau of Lighthouses.

The Weather Bureau is transferred from the Department of Agriculture to the Department of Commerce.

In his message of transmittal the President points out that the groupings proposed are much more logical than the present scattered setup.

No major changes in immediate direction of the work now being carried on by the several bureaus is proposed. In the river and harbor and flood control work the President recommends that the services of engineer officers should continue to be available in the performance of this work.

In addition to the changes covered by the executive orders, the President recommended legislation necessary for other desirable changes, the abolition of certain commissions and the transfer of many purely local activities in Washington from the federal government to the municipal government of the district.

Use of Gasoline Tax on Streets Proposed in Oklahoma Cities

The state legislature of Oklahoma, when it meets in January, will be asked to devote part of the gasoline tax revenues to the maintenance and repair of streets, according to Albert L. McRill, city manager of Oklahoma City. Several cities will join with Oklahoma City in proposing such legislation. Mr. McRill pointed out that all of the $11,000,000 collected last year went to state highway construction and maintenance outside of city limits though much of the tax was paid by urban owners of motor cars.

Abandonment of Raritan Canal Voted by Directors

Directors of the United New Jersey Railroad and Canal Co., at a meeting held in Trenton, N. J., on Dec. 6, voted to abandon the Delaware and Raritan Canal. The canal has been leased to the Pennsylvania Railroad since 1871 and has been losing $250,000 annually during the past few years.

The Delaware and Raritan Canal was opened to traffic in 1834. It extends from tidewater on the Raritan River at New Brunswick, N. J., to Bound Brook and thence to the Delaware River at Bordentown, a distance of about 44 miles.

Abandonment of the canal is being strongly opposed by an organization known as the New Jersey Public Water Highway Committee. This organization would have the canal turned over to the federal government and modernized to see whether sufficient traffic to make it pay cannot be developed.

Contract Let for New Bridge Across St. Lawrence River

Contracts were let recently for the construction of a bridge over the St. Lawrence River between Ville La Salle, near Lachine, Que., and the Indian reservation at Caughnawaga on the south side of the river. The site lies across the Lachine Rapids downstream of the Canadian Pacific Railway bridge. The new bridge will materially shorten the highway traffic route into Montreal from Malone, N. Y., and Adirondack points and will relieve the load on the Victoria Bridge. It will consist of long approach spans of concrete, a number of deck spans of steel including one 231-ft. span which may be converted into a lift span, and a 400-ft. arch span. With the approach fills the total length will be 4,500 ft.

Contract for the piers and concrete work on the approaches was let to A. Janin & Co. for $1,786,000 and for the superstructure to the Dominion Bridge Co. for $773,243. The work is being financed by the Lake St. Louis Bridge Corp. through the issue of bonds guaranteed as to principal and interest by the provincial government. Tolls will be charged until the bonds are paid off. Oliver Lefebvre, chief engineer of the Quebec Streams Commission is acting as chief engineer for the bridge corporation and Ivan E. Vallee, chief engineer of the Department of Public Works and Labour, is consulting engineer.

It is expected that work on the piers and approaches will be carried on throughout the winter.

Power Commissioner Dies

R. B. Williamson, vice-chairman, Federal Power Commission, died suddenly at his home in Washington, D. C., on Dec. 10, age 53 years. Mr. Williamson, a lawyer of Yakima, Wash., has been vice-chairman of the commission since its reorganization in 1930. He has been active in irrigation and hydro-electric work on the Pacific Coast for many years. From 1905 to 1910 he served as legal adviser to the Reclamation Bureau and was one of the drafters of the water code of the state of Washington.

SOCIETY CALENDAR

AMERICAN CONCRETE INSTITUTE, annual meeting, Chicago, Feb. 21-24.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION, Detroit, Mich., Jan. 16-18.

AMERICAN ROAD BUILDERS ASSOCIATION, annual convention and road show, Detroit, Mich., Jan. 16-18.

AMERICAN SOCIETY OF CIVIL ENGINEERS, annual meeting, New York, N. Y., Jan. 18-21.

AMERICAN SOCIETY OF MUNICIPAL ENGINEERS, annual meeting, Detroit, Mich., Jan. 16-18.

AMERICAN TOLL BRIDGE ASSOCIATION, annual meeting, Camden, N. J., Jan. 16-17.

AMERICAN WOOD PRESERVERS ASSOCIATION, Chicago, Ill., Jan. 24-26.

ASPHALT INSTITUTE, Asphalt Industry Conference, Detroit, Mich., Jan. 18.

ASSOCIATED GENERAL CONTRACTORS OF AMERICA, annual convention, Detroit, Mich., Jan. 16-18.

CONSTRUCTION LEAGUE OF THE UNITED STATES, Detroit, Mich., Policy committee assembly, Jan. 21.

HIGHWAY AND BUILDING CONGRESS participated in by twenty national engineering societies and trade associations, Detroit, Mich., Jan. 16-20.

INTERNATIONAL ASSOCIATION OF PUBLIC WORKS OFFICIALS, Detroit, Mich., Jan. 17.

ENGINEERING INSTITUTE OF CANADA, annual meeting, Ottawa, Ont., Feb. 7-8.

NATIONAL CRUSHED STONE ASSOCIATION, annual meeting, Detroit, Mich., Jan. 16-18.

NATIONAL PAVING BRICK ASSOCIATION, annual meeting, Detroit, Mich., Jan. 17-18.

NATIONAL READY MIXED CONCRETE ASSOCIATION, annual meeting, Detroit, Mich., Jan. 17-18.

NATIONAL SAND & GRAVEL ASSOCIATION, annual meeting, Detroit, Mich., Jan. 16-18.

PORTLAND CEMENT ASSOCIATION, Detroit, Mich., Jan. 16-18.

AMERICAN WATER WORKS ASSOCIATION will hold its 53d annual convention in Chicago June 12 to 16.

INDIANA SECTION, American Water Works Association, will hold its annual meeting in Indianapolis March 28-30.

SOUTHWEST ROAD SHOW AND SCHOOL will be held in Wichita, Kansas, Feb. 21-24.

ARKANSAS WATERWORKS CONFERENCE, sponsored by the general extension service, University of Arkansas and the State Board of Health, will be held in Fayetteville, Ark., Feb. 22-25.

GEORGIA SECTION, American Society of Civil Engineers, at a meeting held recently in Atlanta, Ga., elected B. M. Hall, Jr., president; George L. Reed and Oliver H. Lang, vice-presidents, and L. F. Bellinger, secretary and treasurer.

ILLINOIS SECTION, American Society of Civil Engineers, at its Dec. 12 meeting given in honor of Herbert S. Crocker, president, Alonzo J. Hammond, president-elect and C. L. Strobel, recently made honorary member of the parent society, elected the following officers for 1933: President, W. W. DeBerard; vice-president, A. W. Newton, treasurer, C. W. Haupt, F. G. Gordon secretary and S. M. Greeley, vice-president are hold overs. With C. L. Post, past president, the above comprise the executive committee.

Personal Notes

W. B. Ladue, Colonel, Corps of Engineers, U. S. Army, retired from active service on Nov. 30. At the time of his retirement Colonel Ladue, the senior colonel in the Corps of Engineers, was serving as engineer of the 8th Corps area at Fort Sam Houston, Texas. Colonel Ladue graduated from West Point in June, 1894, and after three years at the engineering school and a year on river improvement work on the Ohio was stationed at Newport, R. I., for the planting of submarine mines during the Spanish American war and on fortification construction. Subsequently he was secretary of the Mississippi River Commission in charge of surveys and dredging operations from Cairo to the head of the Passes and secretary and engineer of Moro Province, Philippine Islands. From 1909 to 1913 Col. Ladue was assistant to the Chief of Engineers in Washington, and from 1913 to 1917 Colonel Ladue was on river and harbor and fortification work in Florida and at Charleston, S. C. During the World War he commanded the 314th Engineers, the 603d and the 211th Engineers. From 1919 to 1921 he was in charge of river and harbor work and fortifications on the Delaware River and, after a brief period commanding the 1st Engineers, he went to Corozal, Panama Canal Zone, to take charge of fortification work and to command the 11th Engineers. In 1924 Colonel Ladue returned to become division engineer, North Atlantic Division, at New York. In 1927 he was transferred to Washington as engineer commissioner of the District of Columbia and three years later went to Fort Sam Houston, Texas.

Obituary

William Duval Bailliarge, chief consulting engineer to the city of Quebec, died on Dec. 4, age 69 years. For many years Mr. Bailliarge served as secretary of the Civil Roads Committee in Quebec.

Arthur W. Gunther, Jr., assistant engineer on the U. S. dredging operations on the Mississippi River at Cape Girardeau, Mo., died in St. Louis on Dec. 4, age 24 years. He was a graduate of the Missouri School of Mines.

Arthur C. Tagge, former president of the Canada Cement Co., died suddenly in Montreal Dec. 6, age 63 years. Mr. Tagge had retired from active service in 1930. He was a graduate of the University of Michigan and went to Canada in 1902 as engineer of the International Portland Cement Co.

Rae E. Maynard, 62 years of age, construction engineer and formerly vice-president of the General Petroleum Corp. of California, died Dec. 6 at Los Angeles. He had retired from the corporation eight months ago, after having been in charge of pipe line transportation since 1912. When Mr. Maynard entered the oil business he served as construction engineer for the first oil pipe line built from the San Joaquin Valley to Los Angeles. He previously was a construction engineer for sugar companies in the Territory of Hawaii and served for one year as an investigating engineer in the Malay States.

Brief News

AWARDS OF HIGHWAY CONTRACTS in Texas on bids opened in November, which were held up by an injunction suit, may now be made by the highway commission. The temporary injunction has been dissolved by the Third Civil Appeals Court.

WORK ON THE NEW RESERVOIR for the city of Hobart, Okla., is expected to begin about Jan. 1. Construction of the reservoir has been made possible by the approval of an R.F.C. loan of $250,000 to the city through the purchase of bonds voted in 1931 but not sold.

MUNICIPALITIES IN ALABAMA will not be able to borrow money from the Reconstruction Finance Corporation for municipal work. A constitutional amendment to permit municipalities to borrow funds from the R.F.C. was voted down at the November election.

WORK ON THE TUNNEL to carry Wellington St., Montreal, under the Lachine Canal will be resumed with the closing of the canal to navigation. Work on the tunnel was stopped recently because of an inflow of water from the canal. With the closing of navigation the flow through the canal will be reduced to about 1,400 sec.-ft. thus reducing the possibility of further inflow.

A VEHICLE TUNNEL through the Great Neck Mountains on the new Peekskill-Beacon highway along the east shore of the Hudson River was opened to traffic on Nov. 25. On the old road the tracks of the New York Central Railroad were crossed twice in getting around the mountain. The new road eliminates the two grade crossings and materially improves the alignment.

NEARLY 400 MILES OF ROAD in the province of Quebec will be kept open for winter traffic under the plan now being prepared by the Provincial Highway Department. Experiments in keeping roads open for winter traffic were begun in the 1928-29 season when 84 miles were kept free for motor traffic. The mileage has increased gradually since that time. Last year over $140,000 was spent in this way. The average cost per mile was around $500 for the Quebec area and $350 for the Montreal area.

A RE-SURVEY of the Manitoba-Ontario boundary line which has been in progress for the past two years has been completed. It has resulted in adding about 5,320 square miles of mineral and timber territory to the province of Ontario near the eastern end of Island Lake where the boundary line turns at a 45 deg. angle and runs to Hudson Bay.

Contracts and Capital

CONSTRUCTION

(Thousands of Dollars)

	Weekly Average Dec., 1931	Four Weeks	Week Dec. 15, 1932
Federal government	$3,325	$6,533	$2,393
State and municipal	11,974	9,645	11,790
Total public	$15,299	$16,178	$14,183
Total private	9,727	4,298	4,814
Week's total	$25,026	$20,476	$18,997
Cumulative, Jan. 1 to date:			
1931 construction			$2,404,124
1932			1,182,967

Decrease, 51 per cent.

NEW PRODUCTIVE CAPITAL

(Thousands of Dollars)

	Weekly Average Dec., 1931	Four Weeks	Week Dec. 10, 1932
R.F.C. loans	.....	$900	.....
New capital issues	$6,000	9,100	$7,000
Total	$6,000	$10,000	$7,000
Cumulative, Jan. 1 to date:			
1931 new capital			$2,004,000
1932 R.F.C. loans approved		$139,400	
1932 new capital		764,400	
1932 total			$903,800

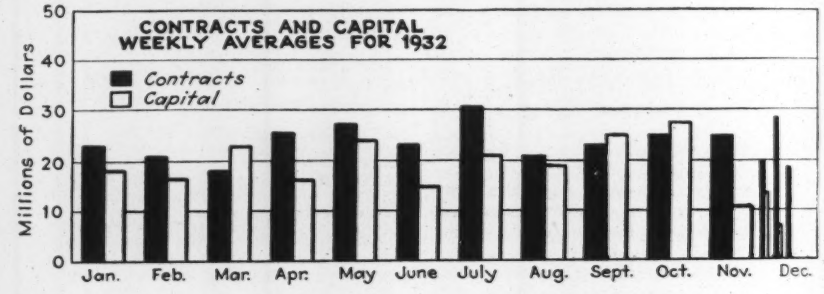
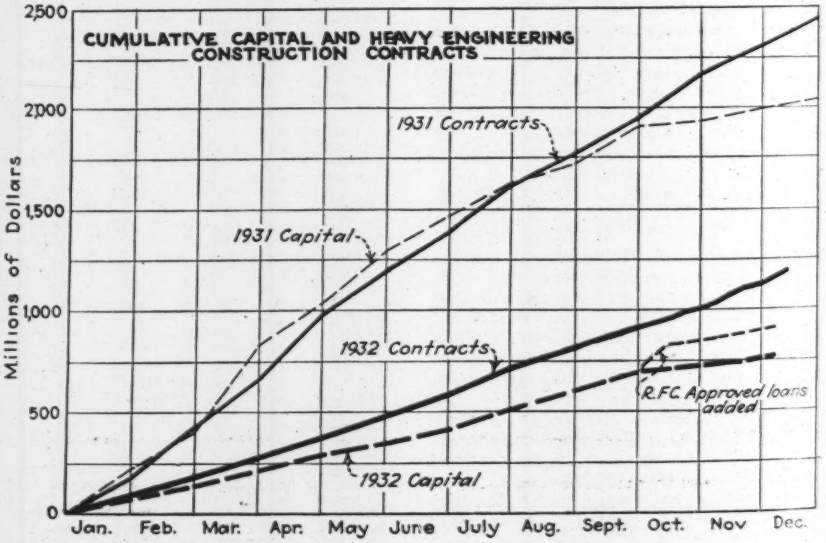
Decrease, 55 per cent.

ENR Cost and Volume Index

Cost		Volume	
December, 1932	**158.46**	**November, 1932**	**137**
November, 1932	158.20	October, 1932	137
December, 1931	166.23	November, 1931	180
1931 (Average)	181.35	1931 (Average)	220
1930 (Average)	202.85	1930 (Average)	260
1913 Average	100.00		

Engineering Contracts and Capital

HEAVY ENGINEERING construction contracts reported for the past week total $18,997,000, about two-thirds of the previous week's total. A drop in federal awards accounted for most of the week's decline, these contracts amounting to $2,393,000 as compared with $10,886,000 the previous week. State and municipal lettings were $11,790,000, about half a million below the former week. Highway awards held up well for this time of year, reaching a total of $6,910,000. Private contracts were average, amounting to $4,814,000. Large contracts reported during the week include a coliseum, Jersey City, $3,000,000; highways, Florida, $1,006,000; highways, Texas, $3,194,000; and a mental hospital, Kings Park, N. Y., $1,781,000.

According to the proposed and bidding list the present construction volume will carry over into the new year. These classes include a federal court house, New York City, 8.2 millions; apartments, Newark, N. J., 7 millions; bridge, Richmond, 2.7 millions; power line, Ft. Wayne, 1 million; hospital, Stapleton, N. Y., 2.5 millions; law building, University of Michigan, 1 million; postoffice, New York, 10.7 millions; sulphur plant Louisiana, 1.5 millions; and million-dollar breweries, two in Brooklyn and one in San Diego. Belleville, Ill., is planning a waterworks system to cost 1.5 millions and an electric light plant estimated at $750,000.

New capital issues for the week ended Dec. 10 amounted to $7,000,000, almost half of which was a $3,000,000 issue of Missouri road bonds. The R.F.C. loans announced during the week are not included in the following figures.